DETERMINING INTRA-THEATER AIRLIFT REQUIREMENTS FROM NUMBER OF PERSONNEL DEPLOYED IN A REGION

GRADUATE RESEARCH PAPER

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Abstract

In today's constrained budget environment, Air Mobility Command struggles with striking the right balance in the mobility force structure. There is political pressure to maintain the status quo, but financial constraints promote downsizing the number of tactical airlift aircraft in the inventory. There must be a dependable way to determine the amount of intra-theater airlift that is required for the force while ensuring assets are in place to provide it.

This research explores an under researched area of study in the Mobility Air Force; namely, what are the actual requirements for intra-theater airlift in a sustained conflict. To achieve this, the researcher applied a backward linear regression analysis to a dataset obtained from an Air Mobility Command database and one from the USCENTCOM Theater of operations. Six years of data were compared to the number of people deployed to the Middle East region and other variables. The researcher attempted to determine what the most influential factors are in the demand for airlift and how those requirements change based on the number of personnel deployed to an Area of Operations. Prediction equations with high correlation coefficients were developed from the datasets and individual variables were examined to determine their effect.

This research project is dedicated to my lovely wife and two children. Thank you for providing the support, love and motivation to keep this project on track.

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I would like to thank my advisor, Lt Col Sandlin, for always keeping me on the right track, Dr. Christine M Schubert Kabban for showing me the way with statistics, Mrs. Shana Anderson for her outstanding computer support, and Mrs. Pamela Bennett Bardot for the best research assistance that I have ever experienced. I couldn't have completed this project without all of your help.

Mark R. Thomas

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DETERMINING INTRA-THEATER AIRLIFT REQUIREMENTS FROM NUMBER OF PERSONNEL DEPLOYED IN A REGION

I. Introduction

Airlift forces are vital instruments of national power. Airlift plays a key role in meeting National Military Strategy requirements. Airlift can bring a constructive force to a crisis, but it can also exert destructive force against an opponent in the form of forcible entry operations in concert with ground units, conducting combat delivery operations to establish a lodgment. Whatever the situation, airlift moves the assets to resolve the contingency according to the security interests of the United States or its allies. (AFDD 3-17)

General Issue

In today's constrained budget environment, Air Mobility Command struggles with striking the right balance in the mobility force structure. There is political pressure to maintain the status quo, but financial constraints promote downsizing the number of tactical airlift aircraft in the inventory. All this must be done with the support of the end user in mind. There must be a dependable way to determine the amount of intra-theater airlift that is required for the force and ensuring assets are in place to provide it.

The support can be provided several ways. First, there is a great deal of commercial and contract airlift in theater. In fact, the Theater Express program has been the government's first choice for moving much of the intra-theater cargo (Huard, 2010: 41).

The U.S. Army also has a limited fixed-wing airlift capability, which primarily consists of C-23 and C-12 aircraft (Stillion et al., 2011: xi). These aircraft conduct many of the same missions as the CH-47 Chinook medium-lift helicopter and provide a small amount of intra-theater airlift. Alternatively, the U.S. Air Force has a doctrinal responsibility for joint air mobility missions and the bulk of the joint capability for fixed-wing air mobility (Stillion et al., 2011: xi).

The Air Force has identified three broad operational mission areas relating to the intra-theater airlift system for the Intra-theater Airlift Functional Area Analysis (FAA), centering it on the system's ability to provide:

1. Routine sustainment: defined as the steady-state delivery of required supplies and personnel to units.
2. Time-sensitive, mission-critical resupply: defined as the delivery of supplies and personnel on short notice, outside the steady-state demands.
3. Maneuver to U.S. and allied forces across all operating environments: defined as the transport of combat teams around the battlefield using the intra-theater airlift system (Orletsky et al., 2011: x).

The Air Force requires a way to determine how much cargo and personnel are required to support a deployed force with intra-theater airlift in these roles.

This study will use historical data to determine if the levels of deployed personnel in a region can be used to accurately forecast the amount of inter-theater airlift demand. An exhaustive review of the literature has not uncovered any evidence a study of this

type has ever been done. Even the Mobility Capabilities and Requirements Study 2016 (MCRS-16) built its assumptions on "military judgment." Similarly, the Mobility Capabilities Assessment 2018 (MCA-18) study currently being produced is only a capability assessment and does not attempt to define requirements. A requirements study will eventually be needed to ensure proper support of joint partners and to allow the Air Force to size the fleet appropriately. The predictive equations generated in this research could then be used to develop the requirements and assist in the completion of such a study.

Research Objectives

There are two primary goals for this study. The first goal is to determine the intra-theater airlift requirement for airlift based on the number of troops deployed to a region. The secondary goal is to examine possible sources of increased demand for intra-theater airlift.

Research Focus

The purpose of this Graduate Research Project (GRP) is to determine the number of pallet position equivalents (PPE) required to support a unit of personnel deployed to an area of responsibility. PPE is defined as the quantity that represents the length of a shipment-unit expressed in 463L pallet length equivalents. A single 463 L pallet is 88” long by 108” wide and is 2 ¼” thick. An empty 463 L pallet has a maximum load capacity of 10,000 pounds. The usable dimensions of the upper surface of a 463 L pallet

are 84” wide by 104” long, allowing a 2” area around the pallet to attach straps, nets, or other restraint devices (Compliance Package International, 2013).

This PPE information could then be used to estimate the size of the C-130/C-17 tactical aircraft fleet required for intra-theater lift within a deployed region in conjunction with the commercial movements to meet all the users’ requirements.

Several questions need to be answered to achieve the research goals. These questions are:

1. Given the number of troops deploying, how much theater airlift demand can be expected?
2. What effect does the infrastructure of a country have on airlift demand?
3. How does the environment (permissive or contested) affect the demand?
4. Has there been a seasonal component that has affected the intra-theater airlift requirements of the current conflict?

This research will determine if these factors affect the demand for intra-theater airlift and, if so, which factor has the biggest influence on actual demand.

Methodology

Air Mobility Command (AMC) leadership is the primary audience; the sponsor is Mr. Don Anderson, HQ AMC/A9. He has provided data on the pallet position equivalents moved from 2006 until the present. The data set contains information from two very different operations (Iraq and Afghanistan). Data was obtained from all sources of intra-theater airlift, including: the Short Take-Off and Landing (STOL) contract,

Theater Express contract, U.S. Central Command (USCENTCOM), Deployment and Distribution Operations Center (CDDOC) contract airlift, and fixed-wing military airlift.

This data set was examined to see what variables have the biggest effect on the demand for airlift. For example, the situation on the ground has varied considerably. Some periods of time can be considered a permissive environment, whereas others have been heavily contested due to the Improvised Explosive Device (IED) threat and during some periods both conditions existed in different parts of the same country. The research attempts to determine how much the environment changes the demand.

The Iraq and Afghanistan data sets were analyzed separately, due to the significant geographic differences. However, both should provide a correlation to the number of troops deployed to the region.

In order to forecast demand for intra-theater airlift and properly size the aircraft fleet, a medium to long term view is needed. Several methods are available to forecast demand for this study. The study examined time series models, subjective models, and regression models.

The oldest and in some cases still the most widely used methods for forecasting the demand for transportation is time-series analysis, or trend-extrapolation (Garvett & Taneja, 1974: 29). These models assume that the behavior being modeled occurs in an identifiable pattern over time. This method is often used where time and data are limited and produces the forecast of a single variable, through the use of historical data for the particular variable. The historical data can be manipulated through the use of sophisticated smoothing techniques. Since time is used to reflect the impact of many

variables, the method is only useful as long as there is no change in this basic trend (Garvett & Taneja, 1974: 29). Time-series analysis is especially useful in producing short term forecasts. For example, fast food restaurants use them to forecast demand by hour of the day (Fitzsimmons, 2011: 458). In particular, forecasts of monthly, weekly, daily and hourly variations can most easily be produced by using time-series models (Garvett & Taneja, 1974: 29). They are most appropriate for forecasting one or two periods into the future.

Subjective models such as the Delphi method, cross-impact analysis and historical analogy are used when sufficient data is unavailable for a quantitative analysis. They utilize experts within a field of study to produce a forecast that covers a fairly long term horizon. The drawback of these methods is that they are very labor intensive and require input from a panel with extensive expert knowledge (Fitzsimmons, 2011: 454). The dynamic nature of the planning environment and the unknown end state coupled with the multitude of scenarios that could emerge, also add to the difficulty of using a subjective model.

The existence of a fairly robust dataset and a longer term time horizon drove the research towards a causal model, namely a regression analysis of the intra-theater data that exist to see if a clear pattern would emerge. This method allows individual variables to be examined to determine their effect on the demand requirements and also produces a prediction expression that can be used to forecast demand in the future. The PPE requirement was used as the response variable. Initially, the predictor variables were the

number of personnel deployed, the 9, 12 and 15 month tour lengths, used by the Army in both theaters, and the status of the Pakistan Ground Line of Communication.

Assumptions/Limitations

The quality of the data set is always of the utmost importance in this type of research. The axiom is "Garbage in, Garbage out." As such, inconsistencies within the data set are a major problem. Every attempt has been made to discard entries that are beyond the capacity of the aircraft. The data is assumed to be normally distributed and any errors are randomly dispersed. Lastly, loose cargo, rolling stock, and initiatives such as the Mine Resistant Ambush Protected (MRAP) vehicle movement could skew the numbers considerably. The MRAP movement could be considered to be politically driven and out of the normal for equipment that would be transported by air. Therefore, care was taken to ensure that all available variables were considered and the most realistic model was created from the data.

The regression model will assume a similar force mix, weapons, and force structures to the ones used in the operations in Iraq and Afghanistan. The model will not include rotary wing or other organic airlift capability inherent to the deployed unit's mission. It would also exclude the Direct Support Apportioned (DS-A) C-130 aircraft embedded with the Regional Command (RC) Army units in Afghanistan, as their primary mission is to reduce the CH-47 hours and allow them to conduct more combat-focused operational missions.

Implications

This research could be expanded on by the professionals at AMC/A9 and USTRANSCOM and could ultimately be helpful to determine the correct mix and number of tactical airlift assets that the Air Force should maintain. It will not be sufficient to determine actual force structure or requirements, but should provide a foundation on which further studies could be built.

Overview

The following pages contain: a literature review to provide background and explore current research on the topic, a methodology section detailing how results were obtained and what data was used, an analysis section where the research can be examined, and finally a conclusion section were the results were interpreted.

II. Literature Review

"An Army without its baggage-train is lost; without its provisions it is lost; without bases of supply it is lost."

—Sun Tzu, The Art of War

Overview

Much research has been accumulated on demand forecasting in general, especially in commercial passenger aviation. Methodologies including regression, Delphi studies, and demand forecasting have all been employed (Garvett, 1974: 9) (Wickham, 1995: 15). Most of this research has been concentrated on short term time-series forecast models (Garvett, 1974: 29). Intra-theater demand and its forecasting during war time have been explored to a much lesser extent.

This literature review will explore some of the factors that affect the intra-theater airlift system. Additionally, the study will look at regression modeling and its usefulness in developing predictive models given a large data set.

Intra-Theater airlift system

To understand the relationship between the personnel deployed to a region and the intra-theater airlift requirements, one must have a cursory understanding of the system as a whole.

Joint Publication 3-17, Air Mobility Operations, defines intra-theater airlift as:

> Intra-theater air mobility operations are defined by geographic boundaries. Air mobility forces assigned or attached to that [Ground Combatant Commander] GCC normally conduct these operations. Intra-theater common-user air mobility assets are normally scheduled and controlled by the theater AOC or joint air operations center (JAOC) if established. The ability to identify and coordinate movement requirements (visible in Joint Deployment and Distribution Enterprise-common systems) is critical to providing theater reach back support from the 618th TACC. When intra-theater air mobility requirements exceed the capability of assigned or attached forces, other mobility forces can support intra-theater airlift using a support relationship. (JP 3-17, 2009: xii)

> The [Director of Mobility Forces] DIRMOBFOR will ensure the effective integration of inter-theater and intra-theater air mobility operations, and facilitate intra-theater air mobility operations on behalf of the [Commander Air Forces] COMAFFOR. The DIRMOBFOR provides guidance to the air mobility division (AMD) on air mobility matters, but such guidance must be responsive to the timing and tempo of operations managed by the JAOC director. (JP 3-17, 2009: xii)

Additionally, the Joint Publication 4-09, Distribution Operations, states that "Distribution execution at the intra-theater level is the responsibility of the GCC and the forces assigned, and occurs in that part of the distribution pipeline extending from intermediate staging bases and [Port of Debarkation] PODs throughout the [Operation Area] OA" (JP-4-09, 2010: xvii).

There are two primary forms of delivery for cargo and personnel within the Area of Responsibility (AOR). They are the hub and spoke method and the direct delivery method.

In the hub and spoke method, cargo and personnel progresses through one or more en-route staging bases to arrive at a main operations base (the hub) or Aerial Port of Debarkation (APOD) within a theater. The hub is the focal point for follow-on intra-theater airlift missions. Cargo and personnel are processed and readied for transshipment

by intra-theater assets to the Forward Operating Base (FOB)—the spokes, throughout the theater. Hub and spoke optimizes air mobility operations when supporting multiple operational commanders and operations (AFDD 3-17, 2011: 43).

Most air shipments are consolidated or aggregated shipments. As with truck shipments, a shipment may change aircraft multiple times between the origin and destination ports, similar to commercial air travelers who need to make connecting flights if no direct flight exists to the desired destination (JP-4-09, 2010: IV-21). The hub and spoke method allows this aggregation of cargo and can provide a level of efficiency to the process.

In contrast, the direct delivery method takes cargo directly from the APOE and delivers it to the FOB directly. Direct delivery avoids both the necessity to deploy airlifters to the theater and to transship cargo. It also results in increased velocity and closure overall. This method of delivery is often limited by the ability of the FOB to accept the larger strategic aircraft and obtain the material handling equipment required to download the cargo. Additionally, the cargo requirements of many of the forward locations are too small to justify the larger capacity of these aircraft.

The inter-theater system and the intra-theater system operate in completely different ways. For example, the peak demand for intra-theater airlift occurs at different times than strategic lift. When different scenarios were run, the MCRS-16 determined that the peak demand for strategic lift occurs during the deployment phase of a major war fight and, more specifically, during the deployment to the second of two nearly simultaneous war fights in accordance with Defense Planning Scenario (DPS) guidance

(MCRS-16, 2010: 4). The demand for intra-theater airlift is at its highest after the majority of the forces are deployed (MCRS-16, 2010: 4). This means that strategic assets such as the C-17 can be used to support intra-theater missions without adding to the overall peak demand for that aircraft.

Intra-theater Airlift Tasks

According to Stilton, in the 2011 Intra-theater Airlift Functional Needs Analysis (FNA), the tasks, conditions, and standards that are important for intra-theater airlift missions include the following:

- transport supplies and equipment to points of need
- conduct retrograde transport of supplies and equipment
- transport replacement and augmentation personnel
- evacuate casualties (Stilton et al., 2011: 5)

Ton-Miles

For freight, the normal demand unit, or metric, is the Ton-mile, and for people the appropriate unit is the passenger-mile. This measure is a unit of freight transportation equivalent to a ton of freight moved one mile and a passenger moved one mile respectively.

These units can present challenges for comparison purposes. They are not homogenous measures. In fact, any combination of weight and distance or passengers and distance that equals a certain number of ton-miles would be considered equal. Because of this difficulty, this study will use PPE as the standard measure. This will

allow the study to take larger bulk material into account as well as small heavier items. It is also much more useful for determining airlift capacity.

Theater Express program

Much of the cargo moved within the United States Central Command (USCENTCOM) Area of Responsibility (AOR) is moved by the Theater Express program. Commercial airlift is used to move non-sensitive Department of Defense (DOD) sustainment cargo and rolling stock (vehicles) to customers throughout the USCENTCOM AOR. The United States Government purchases, on average, $390 million worth of capacity on commercial aircraft each year, which allows the commercial carriers to utilize their own supply chains (Huard, 2010: 38).

The program was started in 2006 as a way to relieve some of the burden on the organic airlift assets and shift more cargo away from the convoy routes (Huard, 2010: 38). This shift of traffic allowed less movement on Iraq's roads where the improvised explosive device (IED) threat was very high.

Additional benefits of the program have included the safety of service members and the effective increase in operational life expectancy of the Air Force's aviation assets. Since its origin, the program has expanded to meet Operation Enduring Freedom's requirements in Afghanistan (Huard, 2010: 38).

Once the mode of travel is determined, all five commercial carriers (Air Transport International, National Air Cargo, UPS, FedEx, and Evergreen) have the opportunity to bid on the cargo by offering a price per pound. The award winner is chosen by the

factors of historical performance (i.e., delivery time and cost) (Huard, 2010: 38). The carrier's performance is determined by the company's ability to deliver cargo within 72 hours and to meet contract terms 85 percent of the time. If these goals are not met, the company will lose points, which will affect its future bids (Huard, 2010: 38). The significant amount of cargo that is moved intra-theater by the Theater Express program is illustrated by Figure 1 below.

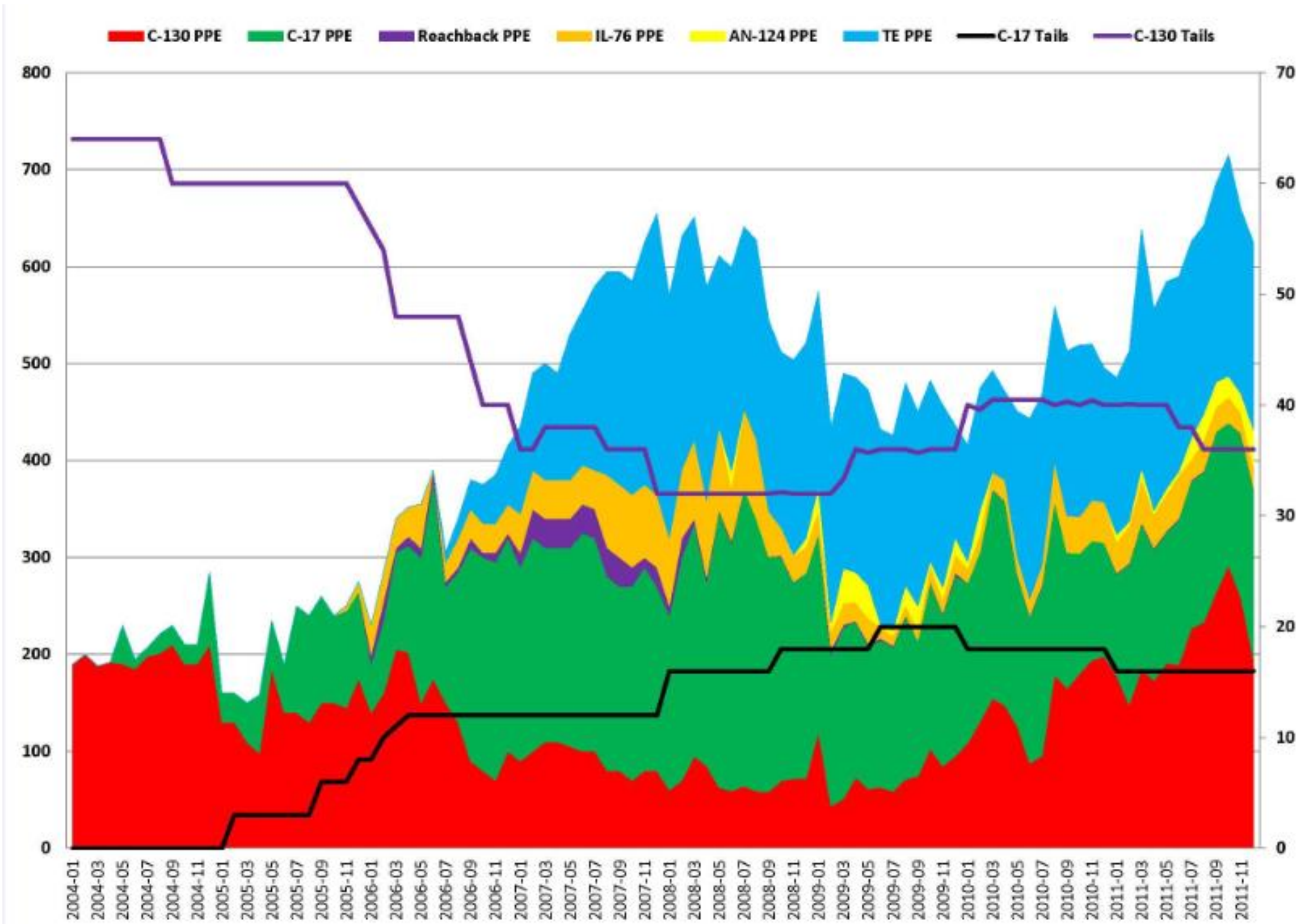


Figure 1**: Intra-Theater Pallets Moved by Aircraft Type**

Source: 609 Air Operations Center, Air Mobility Division

Factors That Affect Demand for Airlift

There are many factors that affect the demand for intra-theater airlift within a theater. Ongoing operations in Afghanistan and Iraq have underscored the vulnerability of ground convoys to attack from irregular and insurgent forces. Supply convoys are vulnerable to ambushes and improvised explosive devices. One of the ways ground supply convoys can be minimized, or in some cases eliminated, is to deliver sustainment and resupply items by air. In addition to eliminating the risks associated with ground resupply operations, aerial resupply offers the potential to reduce delivery times. Implementing more aerial resupply could dramatically increase the need for intra-theater airlift (Stilton et al., 2011: 5).

A second possible source of increased intra-theater airlift demand is the dispersed nature of the global war on terror. This translates to multiple, simultaneous, decentralized operations scattered across huge areas (Stilton et al., 2011: 5).

Another source of increased demand is the huge amount of retrograde and redeployment cargo in the theater that must be moved out of Afghanistan by the 2014 deadline (NY Times, 2012). It should be noted that retrograde cargo is not the same as redeployment cargo and both are dealt with differently within the intra-theater system. Joint publication JP-4-09 defined retrograde as:

> Retrograde is the process of moving non-unit equipment and materiel from a forward location to a reset (replenishment, repair, or recapitalization) program or to another directed area of operations to replenish unit stocks, or to satisfy stock requirements. Retrograde materiel consists of serviceable, unserviceable, economically repairable items and weapons systems destined to a source of repair, refurbishment program, or DRMS. (JP-04-09, IV-23)

This cargo has often accumulated in an area of operations over several years and is no longer assigned to any one particular unit. They are normally items that are common among units and have been designated as "Theater Owned Property" by Army Material Command. This type of cargo will often be put on opportune airlift for transit back to an AOPD for further movement to a stateside location.

Retrograde is the process of moving non-unit equipment and materiel from a unit forward location to a reset (replenishment, repair, or recapitalization) program or to another directed area of operations to replenish unit stocks or to satisfy stock requirements. The distribution-based logistic system relies on the efficient redistribution of intra-theater excesses when they are identified. (JP-04-09, xviii)

This differs from the redeployment cargo that is unit owned and transits back to the home station at the same time as the owning unit. It may travel by surface, sealift or airlift. This type of cargo transits the AOR in a fairly predictable manner, moving in concert with the unit. The amount of both of these types of cargo can add significantly to the demands for airlift support.

Velocity vs. Cost

In a permissive environment, an additional factor to consider is the tradeoff between delivery time and the inventory needed to provide a desired level of customer service and its resulting cost. As replenishment time increases, lead-time demand and lead-time variability increase, requiring more supplies to be on hand for the same level of service. Uncertain wartime environments also lead to a requirement for safety stocks in

theater. So this creates a cost tradeoff among supply chain options if different lead times have different costs (Peltz, et al., 2008: viii).

This can be illustrated by the following example. The RAND study noted that a vehicle battery weighs 89 pounds and has a price of $113. The cost to fly the battery via military-managed strategic air averaged $328 in 2006. Every time a battery is flown, almost three more could be purchased instead for the amount of the airlift bill. The theater inventory costs to relieve the air channel for each single shipment are much less than the cost of one battery, because the inventory continually turns over. In effect, each additional investment in a battery allows up to six demands per year to be satisfied from theater inventory, saving multiple air shipments. The optimal investment in theater inventory for this battery saves $10.1 million per year in transportation costs, with additional annual inventory and materiel handling costs of about $0.5 million for a substantial savings of about $9.6 million per year (Peltz et al., 2008: x).

On the other hand, aircraft engines are big and heavy, so at first glance it seems they should be shipped via surface. However, the Apache and Blackhawk engine, valued at about $700,000 apiece, costs $962 per pound to buy versus $5 per pound to ship by air. First examine what it would take for most engines to be issued from theater inventory. Purchasing additional engines to fill the surface pipeline for theater inventory and produce a high theater fill rate would require $10.7 million in annual inventory holding costs while saving $600,000 in air costs, for a net cost increase of $10.1 million per year. Even at very low theater fill rates, the increased cost of inventory cannot be justified by

the decreased transportation costs, so this item should not be stocked in theater inventory with surface replenishment (Peltz et al., 2008: x).

Passengers from Gateway to final destination

One of the biggest demands for intra-theater airlift is passenger movement. Personnel are normally moved by air due to security and time constraints. In fact, Air Mobility Command has estimated that almost 40 percent of the intra-theater airlift missions flown in the AOR support passenger movements (Anderson, 2013). Each person deployed to a region typically requires one sortie from their gateway destination (the hub that they arrive to the AOR) to their final destination. When their tour is complete, they require air movement back to the gateway to depart the AOR (Anderson, 2013). When coupled with a mid-tour Rest and Recuperation (R&R) this demand is doubled. These tours are provided only for troops that are serving a 12 month tour within the AOR (Anderson, 2013). The two week R&R was eliminated for personnel on 9 month deployments. USCENTCOM has also had varying policies on 3 day passes back to bases away from the forward operating locations. The last passenger requirement for intra-theater lift is for normal movement within the country and can add up to a substantial demand as well (Anderson, 2013).

Passengers take up space on intra-theater aircraft that could be used for moving other cargo. Within the Online Mobility Reporting System (OMRS) database, they are accounted for by using the actual amount of space that they took up on the aircraft including their baggage, in PPE. If actual numbers are unknown, then standard

conversion rate of 11.2 passengers per PPE is used to convert the number of passengers into PPE to input into the system (Anderson, 2013).

Alternate Transportation Methods

Other available means of moving goods and personnel have a huge effect on the requirement for airlift. If safe roads, robust rail networks or inland waterway transportation exist, they remove a considerable burden from airlift systems. The two theaters examined in this study have very different terrain, infrastructure and cargo requirements.

Iraq presented a fairly developed infrastructure with roads between population centers and large port facilities in Kuwait and Basrah. In fact, much of the redeployment and retrograde cargo that came out of Iraq was moved by surface (truck convoy) to Kuwait.

The U.S. Government also sold about $1 billion in military equipment to the Iraqis before departing in 2011 (Army Times, 2011). Additionally, Major General Thomas Richardson, the chief logistics officer in Iraq, stated that U.S. forces had given away equipment with a fair market value of $247 million between Sept. 1, 2010, and August of 2011 -- on top of items worth $157 million that had been transferred before the withdrawal officially started (Froomkin, 2011). This drastically reduced the requirements for airlift to remove cargo from the theater.

It has been a very different story in the late 2011-2012 drawdown in Afghanistan. The terrain is very rugged and unforgiving. Roads are not improved and some are

impassible during certain times of the year. Surface cargo must be transported through one of the neighboring countries and that has created its own difficulties.

The Pakistan Ground line of communication (Pak G-LOC) was closed from November 2011 to July 2012 as a result of the inadvertent killing of 24 Pakistani troops in an airstrike. This was a major blow to the logistics effort in the region (Martinez, 2012). At the time of the closure, Air Force General William M. Fraser III testified before congress, that some 35 percent of the cargo for American forces traveled through Pakistan. The rest moved along the northern supply routes and via airlift (AGENCY GROUP, 2011). Additionally, the Northern distribution network was not fully in place to absorb the added cargo flow. This closure added considerably to the intra-theater airlift requirements. Figure 2 below shows some of the surface routes for the USCENTCOM AOR.

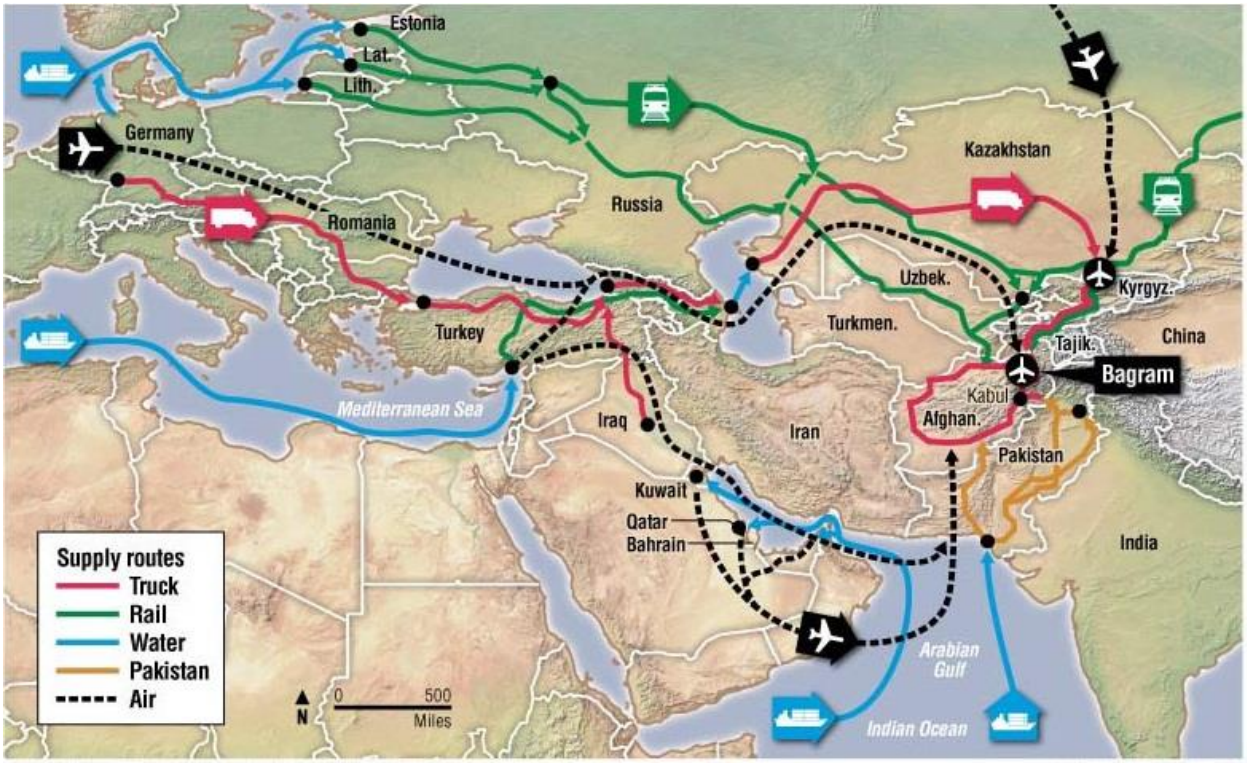


Figure 2: Major Supply Routes in the USCENTCOM AOR

Source: (Army Times, 2011)

Regression Analysis

The purpose of most research is to assess the relationship between data or variables. One way that this can be accomplished is through regression analysis. In statistics, regression analysis is a statistical technique for estimating the relationships among variables (McClave, 2011: 562). It includes many techniques for modeling and analyzing variables, when the focus is on the relationship between a dependent variable and one or more independent variables.

Linear regression is a sub-set of regression analysis. It attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be the predictor, or independent variable, and the other is considered to be a response, or dependent variable. The regression is done to see what affect, if any, the predictor variable influenced the response variable.

In multiple regressions, multiple predictor variables are used to see which has the greatest effect on the response variable. The variable with the highest p - value is typically discarded and the model is run again to see if it improves.

The most common method for fitting a regression line is the method of least-squares (Mathworks, 2013). This method calculates the best-fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line (if a point lies on the fitted line exactly, then its vertical deviation is 0). Because the deviations are first squared, then summed, there are no cancellations between positive and negative values.

The performance of regression analysis methods in practice depends on the form of the data generating process, and how it relates to the regression approach being used. Since the true form of the data-generating process is generally not known, regression analysis often depends to some extent on making assumptions about this process. These assumptions are sometimes testable if a large amount of data is available. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally (Collins, 2010: 177).

History

Regression analysis can be traced back to the 1870s and the pioneering work by Francis Galton, dealing with work on inherited characteristics of sweet peas (Stanton, 2001). While studying natural inheritance, Galton collected data on the heights of adult children and their parents. He noticed that the tendency was for tall parents to have tall children and for short parents to have short children. However, the children were not as tall, or short, as their parents. Their heights tended to move towards the mean height of the overall population. Galton called this phenomenon the "law of universal regression" because the children tended to "regress" towards the average. A straight line model was applied to the height data and the term regression model was coined (McClave, 2011: 562).

For most of its history, regression analysis has been a complex, cumbersome, and expensive undertaking. Around 1944, as part of the war effort, Milton Friedman was asked to analyze data on the alloys used in turbine engine blades. He used regression analysis to develop a model that predicted the time to failure as a function of stress, temperature, and some metallurgical variables representing the alloy's composition. Obtaining estimates for Friedman's equation by hand and calculating test statistics would have taken a skilled analyst about three months' labor. Fortunately, a large computer, built from many IBM card-sorters and housed in Harvard's air-conditioned gymnasium, could do the calculations. Ignoring the time required for data input, the computer needed 40 hours to calculate the regression estimates and test statistics. Today, a regression of

the size and complexity of Friedman's could be executed in about one second (Armstrong, 2012: 689).

Summary

This literature review attempted to provide a background for the discussion that will follow in the rest of the study. It outlined some of the factors that are at work in the intra-theater airlift system and the issues that most affect the flow of cargo. The review also noted a lack of research done on the topic of intra-theater airlift and forecasting of intra-theater demand. The actual regression techniques used in the study will be covered in depth in the methodology section.

III. Methodology

Overview

This section will describe the two data sets used in the research and how they were prepared for the regression analysis. The section then describes how the data was input into the JMP statistical program and how results were obtained.

Dataset

To determine a predictive model to determine the need for intra-theater airlift, this paper will examine two separate data sets. The first set is a data pull from the Global Decision Support System 2 (GDSS2) system. This system is used by the Tanker and Airlift Control Center (TACC) at Scott Air Force Base to manage the mobility assets worldwide. Although intra-theater assets normally fall under the control of the Air Component Combatant Commander and not USTRANSCOM, the information for the flights is entered into GDSS2 by personnel in the local Air Operations Center (AOC). This database provides the integration between classified and unclassified networks and is one of the most comprehensive command and control tool available. Unfortunately, when the outputs from GDSS2 were compared to other databases, there was only about an 85% correlation.

The second dataset that will be analyzed is from Online Mobility Reporting System (OMRS) database. This database only tracks USCENTCOM intra-theater airlift missions flown by US Air Force aircraft and contract commercial carriers. The primary

aircraft it reports on are the C-130, C-17, C-27, IL-76, and AN-124. It does not contain information about the Theater Express mission or any US Army assets. However, this dataset does contain a great deal more information on the amount of cargo that was actually carried on the sorties. It also provides detailed information on the number of passengers that were carried and the amount of pallet position equivalents that their baggage took up. The downside of the OMRS database is that it is classified. All analysis must be conducted on a secure network and the actual data was published in a classified annex. However, when a methodology was developed, the results are unclassified as none of the original data can be determined from the equation itself.

Methodology

The two databases were compared against personal data obtained from United States Central Command J1. This data detailed the number of personnel, both military and civilian, deployed to Iraq and Afghanistan by monthly total. There has been a great deal of fluctuation in the personnel levels between 2006 and 2012. This is due to various surges, drawdowns and political constraints. The levels for each theater can be seen in Figure 3 below.

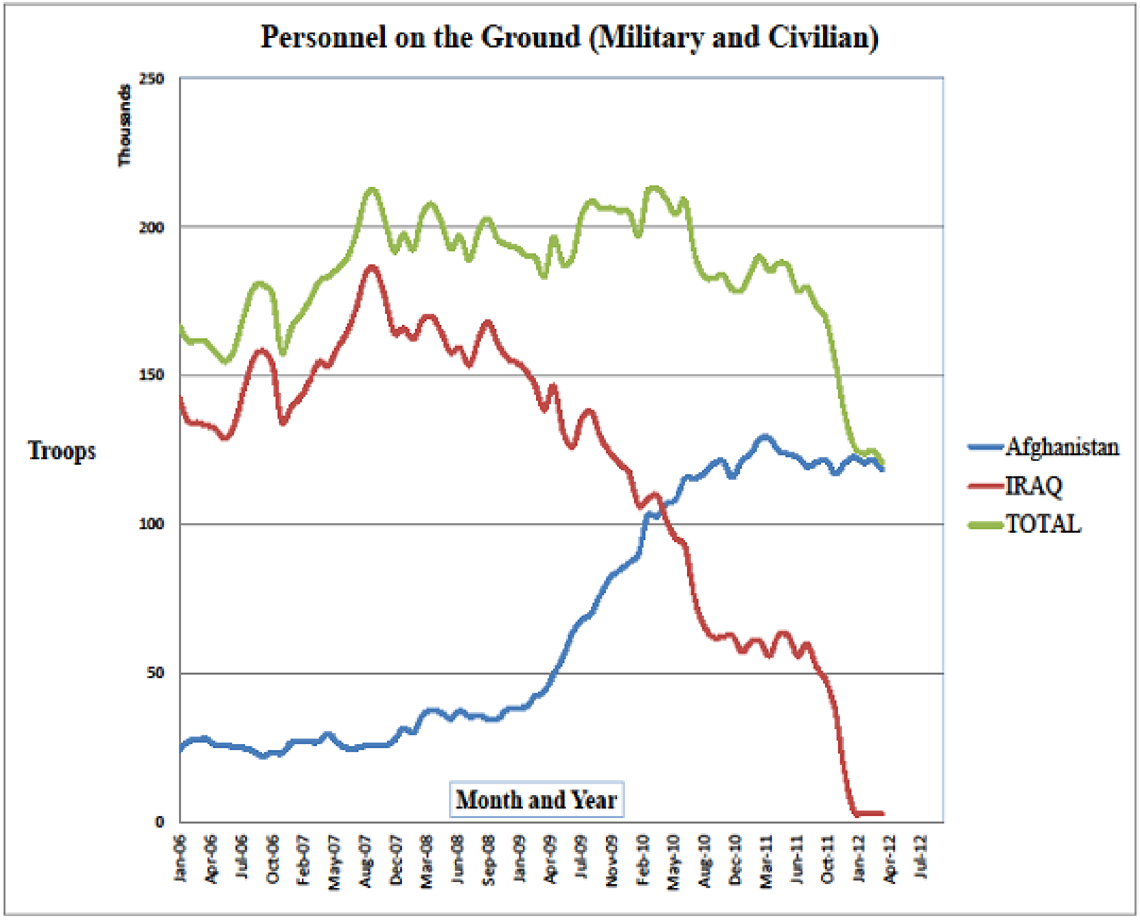


Figure 3: Personnel on the Ground

Source: (CTS Deployment File, Dec 2012)

The first step in the process was to group and sort the cargo and passenger data in Excel. The data from GDSS2 included only sorties that had an origin or destination in the USCENTCOM AOR. The complete list of airport identifiers can be found in appendix B. The data set used has 449,733 individual sorties from January 2006 until August 2012. This data contained each mission sortie, takeoff date, origin, destination, aircraft type, cargo pallet equivalent onboard, rolling stock on board, total cargo weight and a wealth of other information. The data was first sorted by month and year. Then macros in excel were used to separate the sorties that actually transited Iraq and Afghanistan from sorties that did not. The macro then sorted and calculated monthly sums for pallet equivalents and weight for three categories: Iraq, Afghanistan and other.

The OMRS dataset contained the information that was in GDSS2, as well as number of passengers on each leg, PPE for the passengers and their baggage, PPE of cargo for both pallet and rolling stock, and PPE carried overall. A more comprehensive picture of the cargo movement that occurred in the theater of operations appears from this data. It contained nearly 450,000 sorties from Jun 2006 (when the database was started in the AOR) until August 2012. This data set also contained operation designations for each of the sorties. They were: Operation Iraqi Freedom (OIF), Operation New Dawn (OND), Operation Enduring Freedom (OEF), Horn of Africa (HOA), Other and Blank. All sorties that were labeled OIF or OND were counted against Iraq. Likewise, the OEF sorties were counted against Afghanistan. The sorties labeled other or left unlabeled were divided between the theaters based on the percentages of troops deployed to both

countries. Lastly, the HOA sorties were discarded as being outside the scope of this research project.

The data was analyzed in its entirety to determine if there was a relationship between the total movement in the AOR and the population levels of the two active theaters (Iraq and Afghanistan). The J1 personnel data did not include the forces that were deployed to the surrounding gulf region and the first analysis did not show a strong correlation.

The data was then disaggregated into Iraq and Afghanistan sets. This was done for several reasons. First, operations in Iraq had almost entirely come to a close. Military personnel had left the country and the airlift requirements were minimal. Second, the terrain and infrastructure varies greatly between the two regions. Third, the population data that the researcher was able to obtain only included the deployed personnel for Iraq and Afghanistan. Lastly, the two theaters have their own distinct demand signals with different seasonal demand and so distinct models were deemed the best way to proceed.

Sorties with obvious data entry errors (pallets aboard exceeded the capacity of the aircraft) were discarded (approximately 15 data points). Entries for the contracted commercial AN-124s only included cargo pallet information. USCENTCOM policy prohibits moving passengers on these aircraft, so the pallet aboard information was used for the overall PPE carried on these sorties. Additionally, information entered in for the C-27J sorties in the AOR included passengers on board and pallets but not a summed PPE number. On these sorties, passengers were divided by 11.2 to find a pallet

equivalent and that number was added to the cargo pallet number to determine an overall PPE. The instances of both of these data entry problems were approximately 1500 out of the nearly 450,000 sorties in the system. This accounts for well less than .5 percent of the data.

Next, a six step process proposed by McClave and his fellow authors in, *Statistics for Business and Economics* was used to build the probabilistic model used for analyzing a multiple regression model.

Step 1: Hypothesize the deterministic components of the model that relates the mean, E(y) to the independent variables x_1, x_2…….x_k.

Step 2: Use the sample data to estimate unknown parameters in the model β_0, β_1, β_2……. B_k.

Step 3: Specify the probability distribution of the random error term, ε, and estimate the standard deviation of this distribution, σ.

Step 4: Check that the assumptions on ε are satisfied and make model modifications if necessary.

Step 5: Statistically evaluate the usefulness of the model.

Step 6: When satisfied that the model is useful, use it for prediction, estimation and other purposes. (McClave, 2011: 626)

The basic equation of a straight line model is:

$$Y = \beta 0 + \beta 1x + \varepsilon$$

Equation 1

Where: y is the dependent or response variable to be modeled
X is the independent of predictor variable
β_0 is the y-intercept of the line
β_1 is the slope of the line (the change in y for every one unit increase in x)
ε is a random error component

McClave states that there are a set of assumptions that must be used for random error ε. They are that for any given set of values $x_1, x_2\ldots, x_k$, the random error has a probability distribution with the following properties:

1. Mean equal to 0
2. Variance equal to σ^2
3. Normal distribution
4. Random errors are independent (in a probabilistic sense) (McClave, 2011: 626)

The statistics modeling software, JMP 10.0 was used to analyze the data after completing the Excel filtering and grouping. JMP was used to plot the original series, fit a regression line and examine a correlation coefficient.

The correlation of determination is r^2:

$$r^2 = \frac{SS_{yy} - SSE}{SS_{yy}}$$ **Equation 2**

OR

$$r^2 = \frac{\text{explained variation}}{total\ variation}$$ **Equation 3**

Where SS_{yy} is the total sample variation of the observations around the mean y and SSE is the remaining unexplained sample variability after fitting the line. The difference between the two is the explained sample variability that can be attributed to the linear relationship with x.

This coefficient merely measures how well a given regression curve fits the sample data. Whenever two variables have a nonzero correlation coefficient, r, we know that they are dependent in the probability sense. An absolute correlation would be an r^2 of 1and would indicate that all variability is explained. However, r^2 alone does not always provide a complete measure of the predictive power of a model. It is possible to manipulate the model and obtain an r^2 value of 1.0 by over fitting the model, such as a scenario in which the number of predictor variables is equal to the number of data points. Therefore r^2 should be used to measure the usefulness of a model only when the sample size is substantially greater than the number of predictor variables. The adjusted multiple coefficient of determination (Adj- r^2) is more useful since it accounts for both the sample size and the number of predictor variables (McClave and others, 2011: 635). An accepted standard in the statistical community is to only use one predictor for every 10 data points in the model (Schubert Kabban, 2012). While it is important to note that

correlation does not necessarily imply a direct causation, one would assume some causal relationship for a data set of this size.

The complete data set to include all the sorties flown in the gulf was then sorted. Theater Express missions and the missions flown to countries other than Iraq and Afghanistan were assumed to be supporting the theaters in the same proportions as the deployed personnel were distributed. For example, if the distribution was equally split, then half the sorties were assumed to be supporting Iraq and half were assumed to be supporting Afghanistan. The missions that didn't directly transit Iraq and Afghanistan, as well as the sorties with no theater data, like the Theater Express missions, were multiplied by the percentages of personnel in each country and the resulting value was added to the PPE that actually transited the regions. This process was conducted for both the GDSS and the OMRS data sets to obtain the most complete picture possible. This method is the generally accepted practice for dividing information between the two theaters when AMC/A9 conducts studies of this type (Anderson, 2013).

An additional variable was added to the regression to account for the closure of the Pakistan Ground Line of Communication (PAK G-LOC) as this caused a large spike in direct airlift of critical and sustainment cargo. According to USCENTCOM J4 20%-30% of all cargo in Afghanistan is being moved by air. This variable was applied to all months from November 2011 until the present. While the G-LOC officially opened in July of 2012, very little cargo has been moved along it since its original closure.

To account for differing tour lengths and the associated impact on passenger movement requirements three more variables were added. Dummy variables were input

for each of the time frames reflecting the differing tour lengths. The variable was included during the date range where a tour length was in effect and the input for the other two variables was ignored. The three different lengths that were examined were the Army tour lengths used for the Iraq and Afghanistan conflicts; 9 months, 12 months and 15 months. The hypothesis was that a longer tour length would generate fewer requirements than a shorter one because of the extra inflow and outflow of personnel.

The date ranges used in this study information was gathered from open source media outlets. From January 2006 until April 2007 tour lengths were the Army standard 12 months. Then in May 07 tour lengths were changed to 15 months (Associated Press: 2008). This was done to increase the continuity in theater and reduce the demand on the deployment system. During a Pentagon news conference, then Defense Secretary Gates stated: "Effective immediately, active Army units now in the Central Command area of responsibility and those headed there will deploy for not more than 15 months and return home for not less than 12 months,".

This policy applied to all active duty Army units with the exception of two brigades that were already in Iraq and had already been extended to 16 months. The policy did not apply to Marine Corps, Navy or Air Force units serving in Central Command. It also does not apply to Army National Guard or Army Reserve units deployed to the region. The 15-month tour applied to active duty soldiers serving in Afghanistan, the Horn of Africa and all the countries in the region.   In August of 2008 deployments went back to 12 months (Associated Press: 2008). Then in September 2011 tours were dropped again to 9 months (Youssef, 2011).

Residual Analysis

When the outputs from JMP were received, a residual analysis was performed to ensure that the assumptions made were satisfied. As the assumptions all concern the random error component, ε, the first step is to estimate the random error. The error associated with a value of y is the difference between the actual y value and its unknown mean. The researcher estimated the error by taking the difference between the actual y value and the estimated mean. This estimated error is called the regression residual or simply the residual (McClave et al., 2011: 698).

First the residuals were plotted against each of the quantitative independent variables. Each plot was analyzed to determine if there was a curvilinear trend that would indicate the need for a quadratic term in the model.

Next the residual plots were examined for outliers. Lines were drawn on the residual plots at 2 and 3 standard deviation distances from the 0 axis. One would expect that no more than 5 percent of the residuals would exceed the 2 standard deviation line.

The frequency distribution of the residuals was plotted using a histogram to see if they followed a normal distribution. Additionally, any skewedness in the distribution could be caused by outliers, so special care was taken to identify them.

Finally, unequal variance was checked by plotting the residuals against the predicted values of y. Any pattern could indicate that the variance of ε is not constant that the model should be refit (McClave et al., 2011: 702).

Summary

The methodology section detailed the manipulation of the two data sets that was done prior to using the computer program, JMP, to perform an analysis. The 450,000 sorties in each data base were sorted according to group, then by operation, and then by year. Next, they were then compared to the number of military and civilian personnel in each theater during that month.

IV. Analysis and Results

Chapter Overview

This chapter will detail the analysis performed on both the GDSS2 and the OMRS data set and draw conclusions from the results. The investigative questions will then be examined and compared to the models that resulted from the regression.

GDSS2 Dataset

The first model was a regression of total PPE moved in the CENCOM AOR vs. the total number of personnel deployed to both Iraq and Afghanistan. The dummy variables for the 9, 12, and 15 month rotations as well as the variable for the Pakistan G-LOC were included. There were 79 observations in the dataset ranging from January 2006 until July 2012. The Theater express data was added as well.

The regression plot (Figure 4) shows a fairly random distribution with very little correlation. This is confirmed by the very low r^2 value (Table 1) and the high errors. This result is attributed to the personnel data only containing the people deployed to Iraq and Afghanistan. The sizable footprint of military and civilian manpower in the other gulf and AOR countries is not accounted for and appears to be skewing the results. Additionally, as discussed earlier, the demand curve for the two countries is very different. A much larger percentage of sustainment cargo in Afghanistan is shipped by air than in Iraq. In fact, it is a much larger percentage than past conflicts as well.

Even when the gulf countries were removed and only sorties into Iraq and Afghanistan destinations were plotted against each other, there was very little correlation. The models may be so different as a result of the terrain and other constraints that they cannot be modeled together.

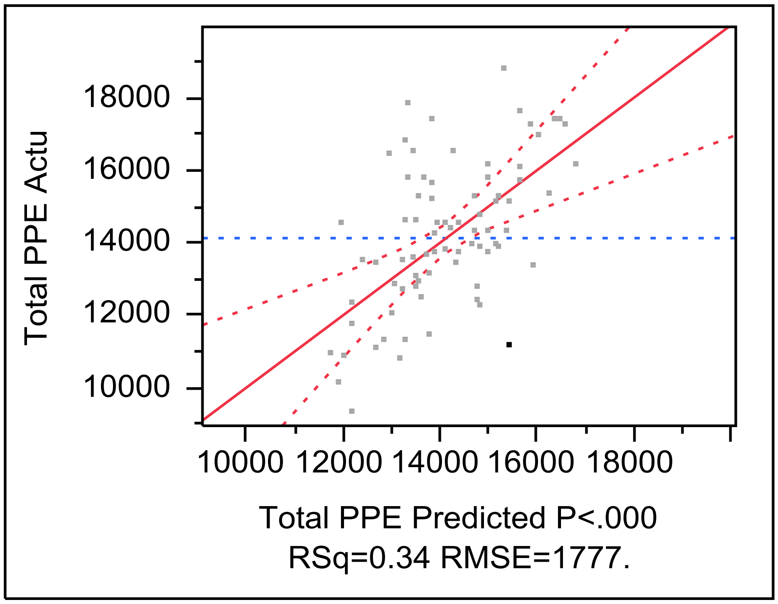


Figure 4: Actual by Predicted Plot for the combined theater

Figure 4 above displays a random distribution of points without the correlation that one would expect. Additionally, the low r^2 value can be seen in Table 1 below.

Summary of Fit

Table 1: Summary of Fit combined theaters (GDSS2)

R Squared Value	0.335453
Adjusted R Squared Value	0.299531
Root Mean Square Error	1777.834
Mean of Response	14127.65
Observations	79

Table 2: Parameter Estimates combined (GDSS2)

Term	Estimate	Std Error	T Ratio	Prob > |t|
Intercept	4353.8122	2745.989	1.59	0.1171
Total BOG	0.0578	0.0138	4.16	<.0001
9 Month Rot	2460.8503	1374.076	1.79	0.0774
12 Month Rot	-1370.385	529.6849	-2.59	0.0116
G-LOC closed	-384.9396	1524.256	-0.25	0.8013

One can see from Table 2, above, the variables of Total BOG, 9 month Rotations, 12 Month Rotations are statistically significant based on their p-values, shown in the

Prob > |t| column. This is the two-tailed test against the alternatives in each direction. Based on this information, the G-LOC closure cannot be said to be significant at the 95% confidence level.

The residual plot, shown in Figure 5, shows a random distribution with no definitive patterns.

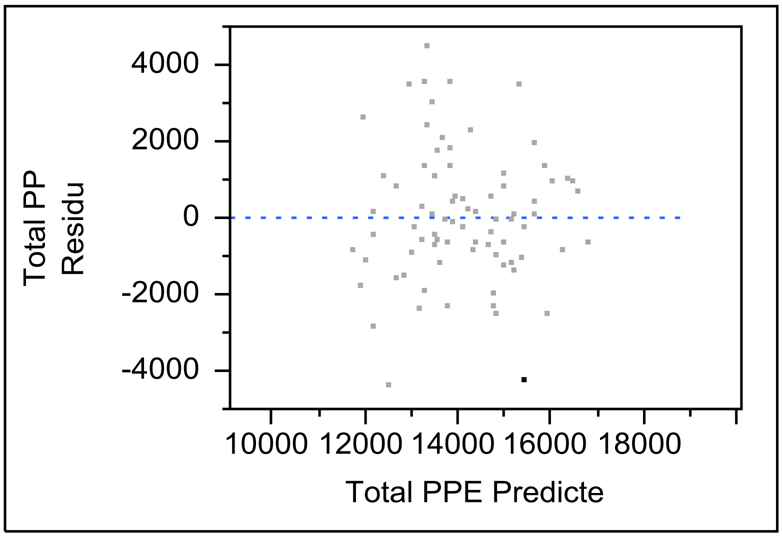


Figure 5: Residual by Predicted Plot (Combined Theater GDSS2)

Iraq Model

When the data is de-aggregated into individual theaters and only the sorties into the countries are taken into account the model becomes much more descriptive. With all the variables in the model the r^2 value jumps to a value of .92. The data shown in Table 3

includes all the variables. Further refinement is accomplished in the next regression.

Figure 6 shows the linear trend and the strong correlation.

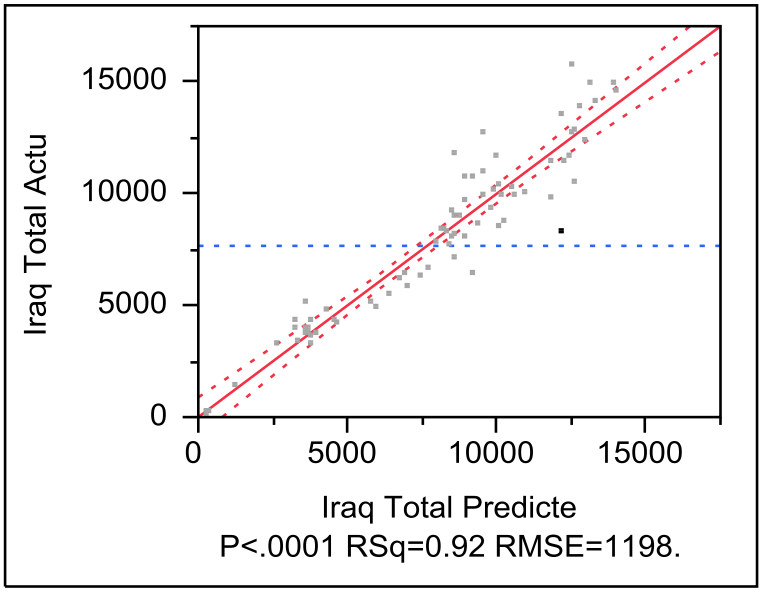


Figure 6: Actual by Predicted Plot (Iraq GDSS2)

Table 3: Parameter Estimates Iraq (GDSS2)

Term		**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	Biased	1349.4259	812.4065	1.66	0.1009
Iraq BOG		0.0686193	0.004571	15.01	<.0001*
9 Month rotation	Biased	-241.6684	1043.304	-0.23	0.8175
12 Month Rotation	Biased	-1880.611	408.7991	-4.60	<.0001*
15 month Rotation	Zeroed	0	0	.	.
Gloc closed		-991.1767	955.7225	-1.04	0.3031

The residuals for this complete model, shown in Figure 7 below, show a random distribution with a mean of 0.

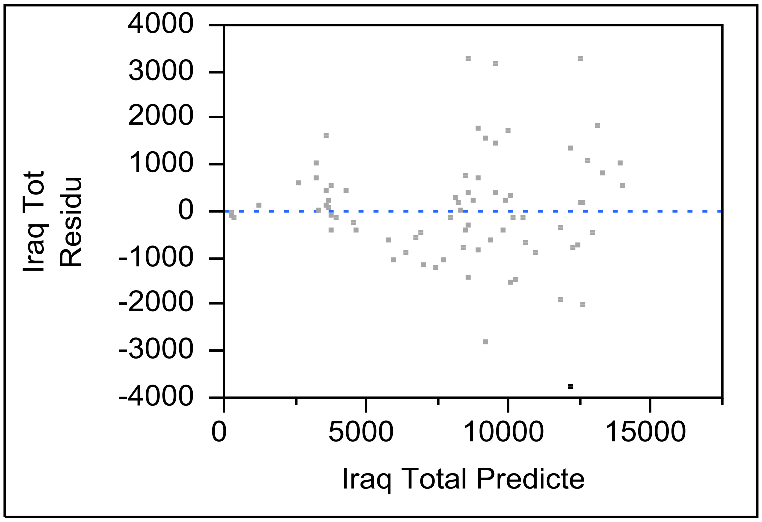


Figure 7**:** Residual by Predicted Plot (Iraq GDSS2)

To find the fit model for Iraq, the regression model was run backwards and the results are shown below. The final model only includes the BOG variable and the 12 months rotation variable. The other rotation lengths were found to be insignificant for this data set. That makes sense given the limitations of the G2 data and its lack of accurate accounting of the passenger and passenger baggage movement within the theater. The model information is shown below.

Prediction Expression

The final prediction expression was:

Total PPE = 396.6756 + 0.0736 * Iraq BOG + -1513.1767 * 12 Month Rotation Variable

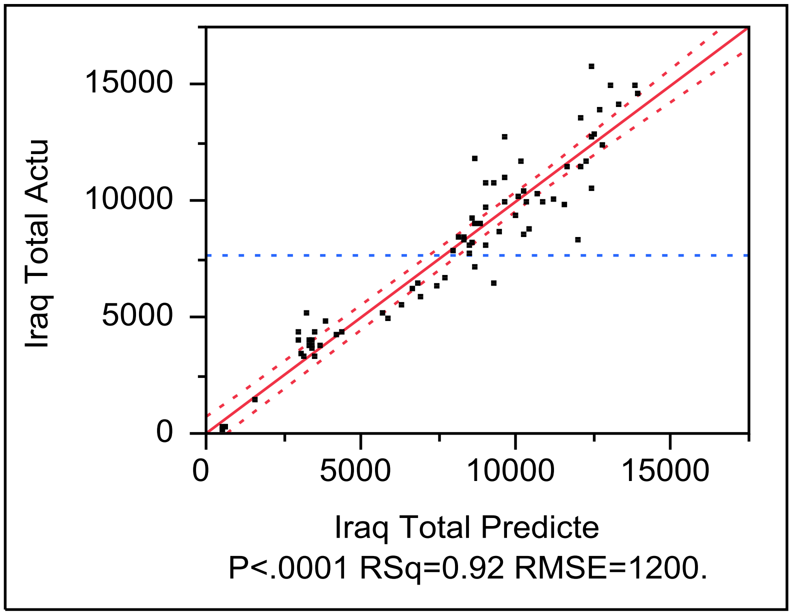


Figure 8**:** Actual by Predicted Plot (BOG and 12 month rotation)

The same strong linear trend from the first iteration of the model can be seen here in Figure 8. The removal of the 9 and 15 month rotation lengths as well as the Pak G-LOC variable had a very small effect on the R Squared value and resulted in a more parsimonious model.

Summary of Fit

Table 4: Summary of Fit Iraq (GDSS2)

R Squared Value	0.915488
Adjusted R Squared Value	0.913264
Root Mean Square Error	1200.893
Mean of Response	7666.152

Observations	79

Table 5, shown below, displays the information on the actual variable terms used in the final model.

Parameter Estimates

Table 5: Parameter Estimates Iraq (GDSS2)

Term	Estimate	Std Error	T Ratio	Prob > |t|
Intercept	396.6755	354.0317	1.12	0.2660
Iraq BOG	0.0736	0.0026	28.61	<.0001
12 Month Rot	-1513.177	286.5915	-5.28	<.0001

Residuals for the model are randomly distributed and the histogram shows no definite patterns (shown in Figure 9).

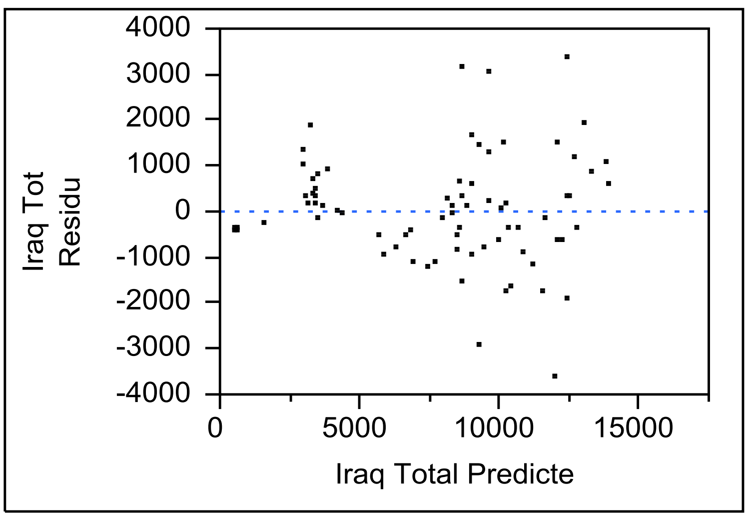


Figure 9: Residual by Predicted Plot (Iraq GDSS2)

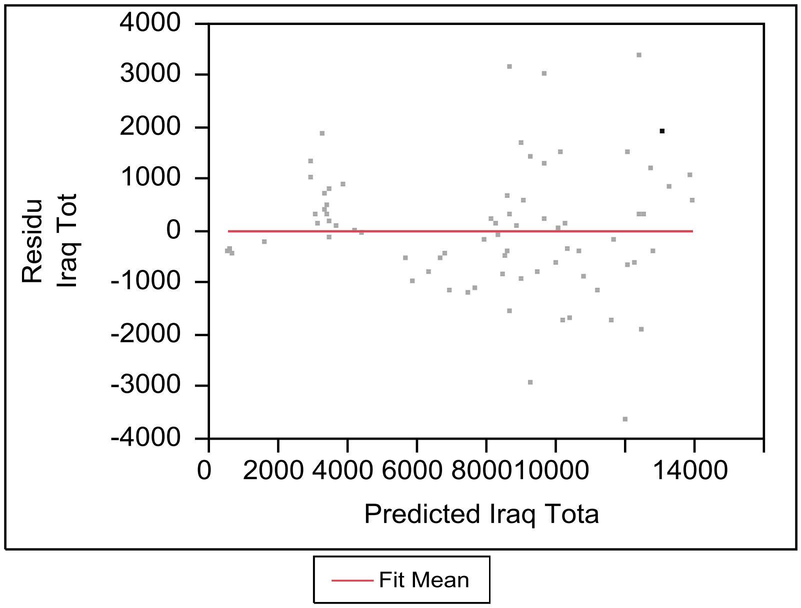


Figure 10: Bivariate Fit of Residual Iraq Total By Predicted Iraq Total (GDSS2)

The fit model of residuals (Figure 10) to predicted values shows a mean of zero with no noticeable patterns. Additionally, the histogram of the residuals, shown below, shows a roughly normal distribution with a peak near zero and steeply declining symmetric tails.

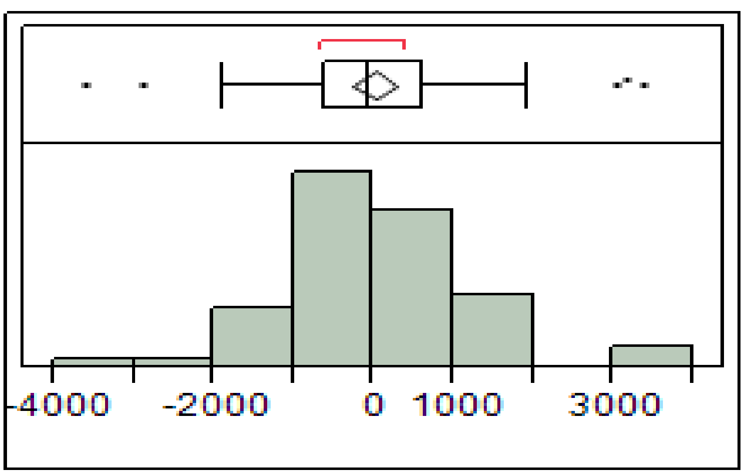


Figure 11: Histogram of Residuals (Iraq GDSS2)

Autocorrelation of the residuals occurs when there the residuals are correlated with lagged values of themselves; that is, when e_t tends to be correlated with e_{t-s}. The Durbin-Watson statistic tests for correlations between e_t and e_{t-1}, which is called serial correlation (Frederick, 2001). The Durbin-Watson statistic will be near 2.0 if there is no autocorrelation. If the statistic is near 0.0, there is evidence of positive autocorrelation (high residuals tend to be followed by high residuals, and negative residuals tend to be followed by negative residuals). On the other hand, if the statistic is near 4, there is evidence of negative autocorrelation (positive residuals tend to be followed by negative residuals, and vice versa) (Frederick, 2001). The values JMP determined for the Iraq model for Durbin-Watson and Auto Correlation are below and show little evidence of Autocorrelation.

Table 6: Durbin-Watson Iraq (GDSS2)

Durbin-Watson number	Number of Observations.	Auto Correlation
1.0326453	79	0.4438

Afghanistan Model

The G2 dataset was then analyzed for the Afghanistan Theater. The best model was shown to include the BOG, 9 month, 12 month and G-LOC variables. A respectable value for r^2 of .88 was determined. The G-LOC variable was found to have the least impact on the overall model and that was a surprising result. The final model is shown below.

Prediction Expression

The final prediction expression was:

Total PPE = 716.2421 + 0.0338 * Afghan BOG + 814.2403 * 12 Month Rotation Variable + 1295.6647 * 9 Month Rotation Variable + 1047.5388 * G-LOC Closed

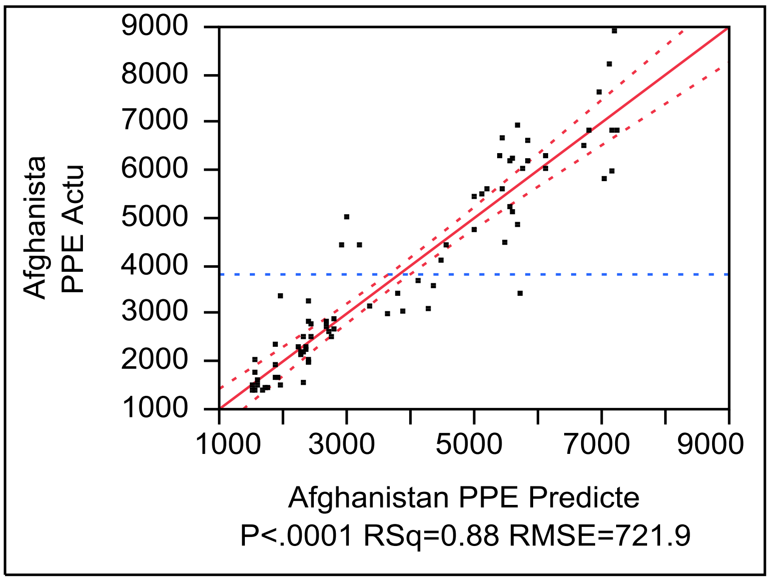


Figure 12: Actual by Predicted Plot (Afghanistan GDSS2)

The same linear trend can be seen in this model as in Iraq, but there are slightly more outliers present.

Summary of Fit

Table 7: Summary of Fit Afghanistan (GDSS2)

R Squared Value	0.875859
Adjusted R Squared Value	0.869149
Root Mean Square Error	721.9762
Mean of Response	3821.101
Observations	79

Table 8: Parameter Estimates Afghanistan (GDSS2)

Term	**Estimate**	**Std Error**	**T Ratio**	**Prob > |t|**
Intercept	716.2421	194.9017	3.67	0.0004
Afghan BOG	0.0338	0.0025	13.67	<.0001
9 Month Rot	1295.6647	587.1798	2.21	0.0304
12 Month Rot	814.2403	226.7758	3.59	0.0006
G-LOC closed	1047.5388	564.4678	1.86	0.0675

Table 8 shows the effect that each of the variables have on the overall prediction expression. The 15 month tour didn't appear to have a significant impact on the overall result.

Again, the same random distribution of the residual values was found when they were plotted against the predicted values.

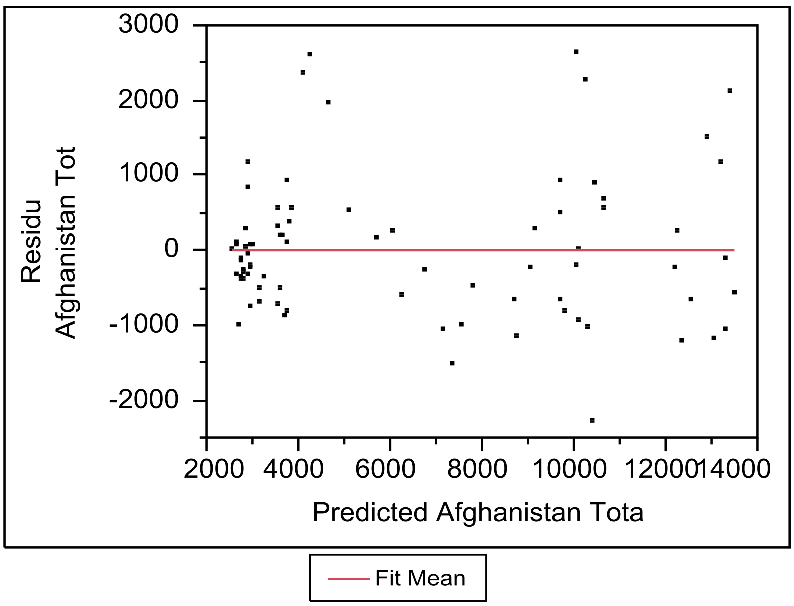


Figure 13: Bivariate Fit of Residual Total By Predicted Afghanistan Total (GDSS2)

The fit model of residuals to predicted values shows a mean of zero with no noticeable patterns. Additionally, the histogram of the residuals, shown below, shows a roughly normal distribution with a peak near zero and steeply declining symmetric tails.

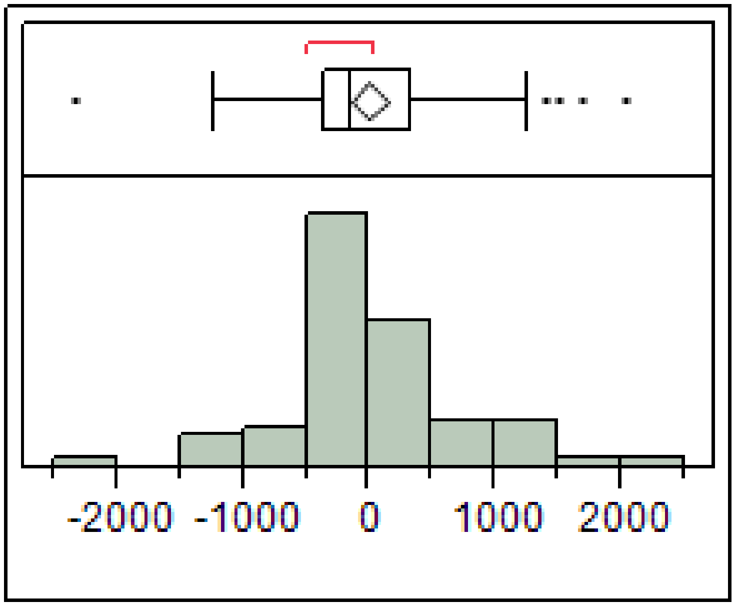


Figure 14**:** Histogram of Residuals (Afghanistan GDSS2)

Table 9: Residuals Afghanistan (GDSS2)

Mean	1.957e-13
Std Dev	703.22038
Std Err Mean	79.118475
Upper 95% Mean	157.51278
Lower 95% Mean	-157.5128
Number of data points	79

The values JMP determined for the Afghanistan model for Durbin-Watson and Auto Correlation are below and show little evidence of Autocorrelation.

Table 10: Durbin-Watson Afghanistan (GDSS2)

Durbin-Watson number	Number of Observations.	Auto Correlation
1.3594335	79	0.3119

OMRS Dataset

The OMRS dataset was dealt with in the same manner as the GDSS2 set. An initial regression on the combined set produced results with very little correlation. As discussed previously, this is due to the demand curves for the theaters being so different.

The set was then disaggregated into an Iraq set, Afghanistan set and other set. This was done based on the operation name that was entered into the OMRS database. The sorties labeled “Other” or “N/A” were divided among the two models based on the percentage of the total number of personnel deployed to both theaters. Most of these sorties had an APOE and an APOD that were not in either theater directly and the researcher could not directly determine what operation they were supporting. Additionally, this method is the accepted practice when AMC/A9 conducts studies of this type (Anderson, 2013). The data from Theater Express was distributed in the same manner. A backwards regression was run in JMP using the deployment length variables and the G-LOC closure variables. Then the Stepwise regression function was used to optimize the model for the lowest AIC in a backwards regression.

Iraq Data

When the data is de-aggregated into individual theaters and only the sorties into the countries are taken into account, the model again becomes much more descriptive.

The final model for the Iraq data had an r^2 value of .9588 and adjusted r^2 value of .9577, shown in table 11 below. As with the GDSS2 data, graphs of the actual values vs. the predicted values showed a linear relationship with few outliers. As expected the closure of the Pakistan G-LOC had very little impact on the model. Surprisingly, the 9 month and 15 month troop rotations were also found to be insignificant.

There were 74 observations in the model and the maximum number of variables used was five.

Table 11: Summary of Fit Iraq (OMRS)

R Squared Value	0.958843
Adjusted R Squared Value	0.957684
Root Mean Square Error	1894.04
Mean of Response	17539.84
Observations	74

The final prediction expression was:

Total PPE = 463.9539 + 0.1658 * Iraq BOG + -2022.8351 * 12 Month Rotation Variable

Table 12: Parameter Estimates Iraq (OMRS)

Term	Estimate	Std Error	T Ratio	Prob > |t|
Intercept	463.9540	599.6954	.83	.4099
Iraq BOG	0.1658	0.0041	40.67	<.0001
12 Month Rot	-2022.835	459.3164	-4.40	<.0001

Table 13: Analysis of Variance Iraq (OMRS)

Source	DF	Sum of Squares	Mean Square
Model	2	5933948803	2.967+9
Error	71	254704535	3587387.8
C. Total	73	6188653338	
F Ratio	827.0571	**Prob > F**	<.0001

The fit model of residuals to predicted values shows a mean of zero with no noticeable patterns. Additionally, the histogram of the residuals shows a roughly normal distribution with a peak near zero and steeply declining symmetric tails. A Studentized Residuals scatterplot shows the data is primarily within 2 standard deviations to fit a 95% confidence interval, as represented within the 2 to -2 range of the plot. There are 6

outliers on this data; this is just above the expected amount for the 74-point data set on a 95% interval.

Afghanistan Model

The OMRS dataset was then analyzed for the Afghanistan Theater. The best model was shown to include the BOG, 9 month, and 12 month variables. A respectable value for r^2 of .95 was determined. As with the GDSS2 data, graphs of the actual values vs. the predicted values showed a linear relationship with few outliers. For this set, the 15 month variable was found to have no impact on the overall model. Additionally, the G-LOC variable had a very slight effect. It did not substantially impact the model and was removed. The final model is shown below.

Table 14: Summary of Fit Afghanistan (OMRS)

R Squared Value	0.953894
Adjusted R Squared Value	0.951918
Root Mean Square Error	1590.016
Mean of Response	14843.7
Observations	74

The final prediction expression was:

Total PPE = 2957.2747 + 0.14762 * Afghan BOG + 4421.2271 * 9 Month Rotation + 1397.2396 * 12 Month

Table 15: Parameter Estimates Afghanistan (OMRS)

Term	Estimate	Std Error	T Ratio	Prob > |t|
Intercept	2957.2747	433.2388	6.83	<.0001
Afghan BOG	0.1476	0.0058	25.52	<.0001
9 Month Rot	4421.2271	807.9101	5.47	<.0001
12 Month Rot	1397.2396	521.934	2.68	.0092

Table 16: Analysis of Variance Afghanistan (OMRS)

Source	DF	Sum of Squares	Mean Square
Model	2	3661333612	1.2204e+9
Error	71	176970511	2528150.2
C. Total	73	3838304123	
F Ratio	482.7421	**Prob > F**	<.0001

The fit model of residuals to predicted values shows a mean of zero with no noticeable patterns. Additionally, the histogram of the residuals shows a roughly normal

distribution with a peak near zero and steeply declining symmetric tails. A Studentized Residuals scatterplot shows the data is primarily within 2 standard deviations to fit a 95% confidence interval, as represented within the 2 to -2 range of the plot. There are 3 outliers on this data; this is an expected amount for the 74-point data set on a 95% interval

Investigative Questions Answered

The questions that the study was seeking to answer were:

1. Given the number of troops deploying, how much theater airlift demand can be expected?

   The number of troops deployed to a given area has been proven to be the most influential factor in determining the airlift requirements to a region.

2. What effect does the infrastructure of a country have on airlift demand?

   The effect of infrastructure on the requirements was not directly proven. It is hypothesized that the requirement will increase dramatically if the theater is in a landlocked country. This appears to be the case in Afghanistan, but the general lack of infrastructure could be causal as well.

3. How does the environment (permissive or contested) effect the demand?

   The study was not able to prove a connection between a contested environment and a corresponding increase in airlift requirements. It is generally accepted that from 2005 and on, both theaters can be considered a contested environment. The only

obtainable data was from 2006 to the present. Therefore, the data set does not allow us to investigate the impact of this variable and it will be included in the undetermined variation.

4. What effect does tour length have on the requirements?

   Tour length was assumed to be a major factor in the increase of airlift requirements, however only the 12 month tour length (the default in both theaters) was shown to be significant in all the models. While it appears to have some effect, it is not as great as was first thought.

5. Has there been a seasonal component that has affected the intra-theater airlift requirements of the current conflict?

The Afghanistan Theater is known to have a seasonal fighting pattern. The data did not show the variance expected from a seasonal pattern in airlift requirements. It could be that the winter season was used to restock supplies that were depleted during the times of heavy fighting, or simply that all the available airlift was being used the entire year and there was no additional capacity to move extra cargo and personnel. No seasonal trend was noted in Iraq.

The global F ratio for all of the de-aggregated models allows us to reject the null hypothesis that the predictor variables have no effect on the response variable. An α=.05 was used for a 95% confidence interval. It was determined that the relationships between the variables were statically significant.

Summary

The datasets were analyzed in this section and four distinct models were developed. There were prediction expressions for Iraq and Afghanistan for both the GDSS2 and the OMRS data. Backwards regression was applied in the JMP statistical software. A model was then selected in each case that provided the best fit.

V. Conclusions and Recommendations

Chapter Overview

This chapter touches briefly on the author's conclusions and significance of the research, and recommendations for action and future research.

Conclusions of Research

The research concluded that only two variables were common to all of the models to determine intra-theater airlift requirements. They were the actual number of personnel deployed to the region and the presence of a12 month tour duration. It was very surprising that some factors such as the closure of the Pakistan G-LOC and the longer 15 month tour length were not found to be statistically significant based on the regression models.

There are many additional factors that are known to affect the model but the researcher was limited by the data available. Some events such as the transition from a permissive environment to a contested environment could not be pinpointed to a specific date or time. This transition happened gradually and incrementally over time and the data did not exist to perform a complete analysis. Most of the transition to a contested environment was thought to have occurred prior to the data set that was used in this research. Additionally, it is difficult to foresee all of the contingencies that may occur in a future conflict. The geography of the next theater of operations could be vastly different than these two.

There is also some anecdotal evidence that a baseline of intra-theater airlift is used regardless of the number of personnel in the region. In other words, the airlift capacity is maxed out because it provides a speed advantage over other forms of transportation. Other methods are then used as the system approaches its capacity.

There were four prediction equations that were determined from the analysis: two for Iraq and two for Afghanistan from the GDSS2 and OMRS datasets respectively. The correlation coefficients were slightly better for the OMRS database for both theaters. More importantly, OMRS includes data for the number of personnel moved and the amount of space required for their luggage. For this reason the two prediction expressions shown below are a more accurate representation of the actual requirements in a theater of operations.

Prediction expression for the Iraq Theater from OMRS

Total PPE = 463.9539 + 0.1658 * Iraq BOG + -2022.8351 * 12 Month Rotation Variable

Prediction expression for the Afghanistan Theater from OMRS

Total PPE = 2957.2747 + 0.14762 * Afghan BOG + 4421.2271 * 9 Month Rotation + 1397.2396 * 12 Month

Significance of Research

If a relatively complete forecasting model could be derived from the data gathered in the operational theaters, it would provide planners with a starting point for the

requirements of intra-theater airlift assets for each operation. This data could then be complied to develop a comprehensive study of what aircraft the Air Force should invest in to acquire and maintain the capabilities that the Combatant Commanders needs. It might also provide a list of variables that planners could use to influence the need for airlift in an operation. For example, if the model showed that a 3-day pass program or R&R required an additional 3 C-130s to be deployed to a region, leadership could objectively compare that cost to other needs in the theater and make an informed decision.

Additionally, this model could be expanded on by the professionals at AMC/A9 and USTRANSCOM and could ultimately be helpful to determine the correct mix and number of tactical airlift assets that the Air Force should maintain. It could be used to defend the Air Force's position with regard to what the force structure should look like and how it should be distributed.

Recommendations for Future Research

Studies or models should be performed that take into account variables such as a more fully developed data set, the complete drawdown from Iraq and the continuing one in Afghanistan, and surges in both countries.

The models for Iraq and Afghanistan should be merged to develop a universal model. Afghanistan is a very difficult area to move cargo and personnel. This is mostly due to the poor infrastructure and the fact that it is a landlocked country. According to *The Central Intelligence Agency World Fact Book*, the number of landlocked countries in

the world is only 44 out of 195. Since just 22 percent of the countries in the world are landlocked, it is recommended that the model be weighted in favor of the Iraq model at a rate of 4 to 1. This should provide a general model for basic planning factors regardless of the actual geographical location.

The new weighted expression could then be compared against the results of the modeling done for the MCRS-18, and checked for accuracy. The combination of the modeling software and the results from past data could provide decision makers with a better understanding of requirements for future conflicts.

Summary

The methodology of this research consisted of a regression analysis of an unclassified dataset (GDSS2), to refine variables and expand understanding of the problem. Using information gained from that exercise, an additional regression analysis was performed, using the same steps, on a more robust and classified database (OMRS). Both regressions showed a strong correlation between intra-theater airlift requirements and the number of civilian and military personnel deployed to a region. The lengths of Army tours within the region were also shown to be correlated to the number of PPE being moved.

Appendix A – ICAOs Used for GDSS2 Search

Departure ICAO_GDSS		Departure ICAO_GDSS		Departure ICAO_GDSS		Departure ICAO_GDSS		Departure ICAO_GDSS		Departure ICAO_GDSS	
OA1A	CARLSON LZ	OEHL	HAIL	OIYY	YAZD	OPKC	JINNAH INTL	ORK2	K2	UA35	PETROPA VLOVSK SOUTH
OA1X	BAGRAM	OEJB	JUBAIL	OIZC	CHAH BAHAR	OPKD	HYDERA BAD	ORK3	K1	UAAA	ALMATY
OABN	BAMYAN LZ	OEJD	JEDDAH	OIZE	CHAH BAHAR	OPKH	KHUZDA R	ORK4	KHAN BANI SAD	UAC1	CHOLPON -ATA
OABT	BOST (LZ)	OEJE	KING ABDULL AH BIN ABDULA ZIZ	OIZH	ZAHEDA N INTL	OPKT	KOHAT	ORK5	KARBAL A NORTHE AST	UACC	ASTANA INTL
OACB	CAMP BASTION LZ	OEJF	KING FAISAL NAVAL BASE	OIZJ	JASK	OPLA	ALLAMA IQBAL INTL	ORKK	KIRKUK AB	UACP	PETROPA VLOVSK
OACC	CHAKHCH ARAN (LZ)	OEJN	KING ABDULA ZIZ INTL	OJ1X	KING FAISAL	OPMI	MIANWA LI	ORM1	MUDAYSI S	UADD	TARAZ
OADR	DWYER	OEK1	AL KHARJ	OJ2X	SHAHE ED MWAFF AQ	OPMJ	MOENJO DARO	ORM2	AL MUHAM MADI	UAFF	FRUNZE
OADY	DWYER LZ	OEKH	AL KHARJ	OJ38	ZARQA	OPMR	MASROO R	ORMM	BASRAH INTL	UAFM	MANAS
OAFR	FARAH (NON- AIRFIELD- C2IPS OPS ONLY)	OEKJ	PRINCE SULTAN AIR BASE	OJ39	KING FAISAL	OPMT	MULTAN INTL	ORN1	AN NUMANI YAH	UAFO	OSH
OAFZ	FEYZABA D	OEKK	KING KHALED MILITAR Y CITY	OJ3X	H 4	OPNH	NAWABS HAH	ORN2	AL NAJAF	UAFW	KANT
OAG1	GHUR GHURI	OEKM	KING KHALED AB	OJ40	SHAHE ED MWAFF AQ	OPPI	PASNI	ORN3	NUKHAY B	UAII	SHYMKEN T
OAGZ	GARDEZ	OEMA	PRINCE MOHAM MAD BIN ABDULA ZIZ INTL	OJ4X	WADI EL MURBA H HWY STRIP	OPPS	PESHAW AR INTL	ORNI	AL NAJAF	UAK2	KOKCHET AV TROFIMO VKA
OAHR	HERAT	OENG	NEJRAN	OJA2	KING ABDULL AH II	OPQS	QASIM	ORNJ	AL NAJAF	UAK3	KZYL ORDA SE
OAIX	BAGRAM	OENR	NARIYA	OJAC	PRINCE HASAN	OPQT	QUETTA INTL	ORQ1	QAYYAR AH WEST	UAKD	ZHEZKAZ GAN
OAJL	JALALABA D	OEPA	QAISUM AH	OJAF	MARKA INTL	OPRK	SHEIKH ZAYED INTL	ORQ2	QALAT SIKAR	UAKK	KARAGAN DA
OAKB	KABUL INTL	OEPC	PUMP STATIO N 3	OJAI	QUEEN ALIA INTL	OPRN	BENAZIR BHUTTO INTL	ORQ3	QASR TALL MIHL	UAOO	KZYLORD A

OAKN	KANDAHAR	OEPS	PRINCE SULTAN AB	OJAM	MARKA INTL	OPRQ	RAFIQUI	ORQ4	QAYYARAH SOUTH	UASK	UST KAMENOGORSK
OAKS	KHOST	OERF	RAFHA	OJAQ	AQABA KING HUSSEIN INTL	OPRS	RISALPUR	ORQ5	QALAT SALIH	UASS	SEMIPALATINSK
OAMN	MAIMANA	OERK	KING KHALED INTL	OJHF	PRINCE HASAN	OPSD	SKARDU	ORQT	QASR TALL MIHL	UATE	AKTAU
OAMS	MAZAR E SHARIF	OERM	RAS MISHAB	OJHR	H 4	OPSF	SHAREA FAISAL	ORQW	QAYYARAH WEST	UATG	ATYRAU
OAQA	QALAT	OERR	ARAR	OJKF	KING FAISAL AB	OPSK	SUKKUR	ORR1	AR RUMAYLAH SOUTHWEST	UATT	AKTYUBINSK
OAQN	QALA I NAW	OERT	RAS TANURA	OJMF	KING HUSSEIN	OPSM	BANDARI	ORR3	RASHEED	UAUU	KOSTANAY
OARM	DELARAM	OERY	RIYADH AB	OJMS	SHAHEED MWAFFAQ	OPSR	MUSHAF	ORR4	RADIF AL KHAFI	UT1X	PETROPAVLOVSK SOUTH
OASA	SHARONA AIRSTRIP	OESB	SHAYBA	OK1X	AHMADI	OPSS	SAIDU SHARIF	ORR5	RUWAYSHID	UT5X	KANT
OASD	SHINDAND	OESH	SHARURAH	OK2X	ALI AL SALEM AIR BASE	OPST	SIALKOT INTERNATIONAL	ORS1	SAMARRA EAST		
OASG	SHEBERGHAN	OESK	AL JOUF	OKAD	DOHA AHP	OPSV	VALIDATION AIRFIELD #8	ORS2	AL SAHRA AAF		
OASH	SHANK	OESL	SULAYEL	OKAF	AHMED AL JABER AB	OPTA	TARBELA DAM	ORS3	AS SALMAN NORTH		
OASL	SALERNO LZ (SEMI-PREPARED)	OET4	THUMAMUH	OKAJ	AHMED AL JABER AB	OR10	SHAYKH MAZHAR	ORS4	SAFWAN		
OATN	TEREEN	OETB	TABUK	OKAS	ALI AL SALEM AB	OR15	SUBAKHU	ORS5	SAHL SINJAR		
OAUZ	KONDUZ	OETF	TAIF	OKBK	KUWAIT INTL	OR1A	RASHEED	ORS6	SALMAN PAK EAST		
OAZ1	CAMP BASTION LZ	OETH	THUMAMAH	OKDI	UDAIRI AAF	OR1X	H2	ORS7	SALUM		
OAZ2	DEH DADI LZ	OETR	TURAIF	OL1X	KLEIAT	OR2A	AS SULAYMANIWAH WEST	ORS8	SHAB AL HIRI		
OAZ3	SHARONA AIRSTRIP	OEWD	WADI AL DAWASIR	OL2X	RAYAK	OR2X	H 3	ORS9	SHAIBAH		
OAZ4	SARHAWADZA LZ	OEWJ	WEJH	OLBA	RAFIC HARIRI INTL	OR3X	H-3 HIGHWAY STRIP	ORSH	AL SAHRA AAF		
OAZI	CAMP BASTION	OEX1	PRINCE SULTAN AIR	OLKA	RENE MOUAWAD	ORA1	AL TAQADDUM	ORSJ	SAHL SINJAR		

			BASE						
OAZJ	ZARANJ	OEXX	MAC ALCC DEPLOYED	OLRA	RAYAK	ORA2	AN NUMANIYAH	ORSU	SULAYMANIYAH INTL
OBBI	BAHRAIN INTL	OEYN	PRINCE ABDUL MOHSIN BIN ABDUL AZIZ	OLW1	WUJAH AL HAJAR	ORA3	AL ASAD AB	ORT1	TALL AFAR
OBBS	ISA AIR BASE	OIA1	AMINABAD LZ	OM01	BURAYMI DAUDI	ORA4	AS SALMAN NORTH	ORT2	TALLIL
OBKH	SAKHIR AB	OIAA	ABADAN	OMAA	ABU DHABI INTL	ORA5	AL FATHAH	ORT3	TIKRIT SOUTH
OE01	ABRAQ AL KIBRIT	OIAD	DEZFUL AB	OMAD	AL BATEEN INTL	ORA7	AL ISKANDARIYAH NEW	ORT4	AL TAJI AAF
OE02	AD DIBDIBAH	OIAG	AGHA JARI	OMAH	AL HAMRAH AUX	ORA8	AL MUFRASH	ORT5	TAL ASHTAH NEW
OE04	AL MUSANNAH	OIAH	GACH SARAN	OMAJ	JEBEL DHANA	ORA9	AMARA NEW	ORT6	TIKRIT EAST
OE05	AL MUSANNAH SOUTH	OIAJ	OMIDIYEH AB	OMAL	AL AIN INTL	ORAA	AL ASAD AB	ORT7	TUZ KHURMATU
OE06	AL QARAAH WEST	OIAM	BANDAR MASHUR	OMAM	AL DHAFRA	ORAI	AL ISKANDARIYAH NEW	ORTF	TALL AFAR
OE07	AL WARIAH	OIAW	AHWAZ	OMAS	DAS ISLAND	ORAN	AN NUMANIYAH	ORTI	AL TAJI AAF
OE08	AL WARIAH SE HWY LDG STRP	OIBB	BUSHEHR	OMDB	DUBAI INTL	ORAT	AL TAQADDUM AB	ORTK	TIKRIT EAST
OE09	AL WADIA	OIBK	KISH ISLAND	OMDM	MINHAD AB	ORB1	BALAD SOUTHEAST	ORTL	ALI BASE
OE11	DUMAYYIGH	OIBL	BANDAR LENGEH	OMDW	AL MAKTOUM INTL	ORB2	BAQUBAH	ORTS	TIKRIT SOUTH
OE12	MUNAYSIFAH	OIBQ	KHARK ISLAND	OMFJ	FUJAIRAH INTL	ORB3	BASHIQAH	ORU1	UBAYDAH BIN AL JARRAH
OE13	RAS KHAFJI	OICC	SHAHID ASHRAFI ESFAHANI	OMRK	RAS AL KHAIMAH INTL	ORB4	BASHUR	ORU2	UMM QASR
OE14	RAS MISHAB SOUTH	OICK	KHORRAMABBAN	OMS1	SAFRAN	ORB5	BASRAH MAQAL	ORUB	UBAYDAH BIN AL JARRAH
OE15	RAS SAFANIYA	OIFM	ESFAHAN SHAHID	OMSJ	SHARJAH INTL	ORBA	ERBIL NORTHWEST	ORUQ	UMM QASR

			BEHESTI						
OE16	SAKHAYL	OIFP	BADR	OMSM	SAFRAN	ORBB	SIRSENK	ORW1	WADI AL KHIRR NEW
OE17	SUFLA	OIGG	RASHT	OMXX	SAFRAN	ORBD	BALAD SOUTHEAST	OSDI	DAMASCUS INTL
OE19	HADHAR	OIH1	HOSEY NABAD	OOMA	MASIRAH	ORBI	BAGHDAD INTL	OTA1	AL UDEID
OE20	JELADY	OIHS	HAMADAN AB	OOMN	AL MUSANA AIR BASE	ORBK	KIRKUK	OTBD	DOHA INTL
OE24	THADJ	OIII	MEHRABAD INTL	OOMS	MUSCAT INTL	ORBM	MOSUL	OTBH	AL UDEID AB
OEAB	ABHA	OIJ1	JAMBOZEH	OOSA	SALALAH	ORBR	BASHUR	OY74	AL ANAD
OEAH	AL AHSA	OIJA	BEHBEHAN NW	OOTH	THUMRAIT	ORBS	BAGHDAD INTL	OYAA	ADEN INTL
OEAZ	KING ABDUL AZIZ NAVAL BS	OIKB	BANDAR ABBASS INTL	OP12	BANDARI	ORER	ERBIL INTL	OYAT	ATAQ
OEBA	AL BAHA	OIKK	KERMAN	OP20	MINHAS	ORG1	GHALAYSAN NEW	OYGD	AL GHAIDAH INTL
OEBH	BISHA	OIKM	BAM	OP22	RAJANPUR	ORH1	H1 NEW	OYHD	HODEIDAH
OEBQ	ABQAIQ	OIKQ	DAYRESTAN	OP37	PANO AQIL SOUTH EAST	ORH2	HABBANIYAH	OYRN	MUKALLA INTL
OEDF	KING FAHD INTL	OIMM	MASHHAD INTL	OPB1	BANDARI	ORH4	H3 NORTHWEST	OYSN	SANAA INTL
OEDR	KING ABDULAZIZ AB	OINN	NOSHAHR	OPBW	BAHAWALPUR INTL	ORH5	H3 SOUTHWEST	OYSQ	SOCOTRA INTL
OEFD	DAMMAMSA	OINR	RAMSAR	OPDG	D G KHAN INTL	ORJ1	JALIBAH SOUTHEAST	OYSY	SAYUN INTL
OEGN	KING ABDULLAH BIN ABDULAZIZ	OISS	SHIRAZ SHAHID DASTGHAIB INTL	OPFA	FAISALABAD INTL	ORJ2	JUWARIN HIGHWAY STRIP	OYTZ	GANED
OEGS	GASSIM	OITR	UROMIYEH	OPGT	GILGIT	ORJA	JALIBAH SOUTHEAST	SHAM	BANDARI
OEGT	GURIAT	OITT	TABRIZ	OPJA	SHAHBAZ AB	ORK1	KUT AL HAYY EAST	UA1X	UST KAMENOGORSK

Appendix B – Theater Express Data

Date	Weight	Pallet		Date	Weight	Pallets
Oct-06	4,505,713	1408		Sep-09	19,659,962	6144
Nov-06	10,163,908	3176		Oct-09	21,564,306	6739
Dec-06	10,004,441	3126		Nov-09	21,339,350	6669
Jan-07	12,754,187	3986		Dec-09	14,290,848	4466
Feb-07	11,619,988	3631		Jan-10	13,853,747	4329
Mar-07	15,952,207	4985		Feb-10	14,785,899	4621
Apr-07	14,734,404	4605		Mar-10	12,332,053	3854
May-07	19,305,637	6033		Apr-10	10,686,116	3339
Jun-07	18,601,594	5813		May-10	15,479,989	4837
Jul-07	20,415,523	6380		Jun-10	19,336,492	6043
Aug-07	25,858,758	8081		Jul-10	18,274,464	5711
Sep-07	25,139,793	7856		Aug-10	16,382,677	5120
Oct-07	26,841,518	8388		Sep-10	19,094,777	5967
Nov-07	26,078,179	8149		Oct-10	19,463,845	6082
Dec-07	32,191,541	10060		Nov-10	16,948,035	5296
Jan-08	26,783,370	8370		Dec-10	14,146,708	4421
Feb-08	23,261,423	7269		Jan-11	15,736,911	4918
Mar-08	23,464,572	7333		Feb-11	18,558,361	5799
Apr-08	23,321,746	7288		Mar-11	18,955,795	5924
May-08	18,245,516	5702		Apr-11	21,513,057	6723
Jun-08	14,428,420	4509		May-11	22,470,489	7022
Jul-08	18,858,523	5893		Jun-11	21,083,441	6589
Aug-08	21,930,412	6853		Jul-11	21,733,386	6792
Sep-08	18,054,962	5642		Aug-11	26,146,425	8171
Oct-08	17,807,600	5565		Sep-11	21,809,519	6815
Nov-08	20,501,872	6407		Oct-11	24,176,176	7555
Dec-08	19,935,067	6230		Nov-11	21,729,255	6790
Jan-09	22,011,630	6879		Dec-11	21,666,431	6771
Feb-09	21,330,714	6666		Jan-12	15,192,405	4748
Mar-09	27,133,848	8479		Feb-12	12,618,178	3943
Apr-09	22,120,924	6913		Mar-12	14,420,556	4506
May-09	25,248,700	7890		Apr-12	12,693,542	3967
Jun-09	24,248,158	7578		May-12	14,870,240	4647
Jul-09	24,582,507	7682		Jun-12	10,994,127	3436
Aug-09	23,327,065	7290				

Appendix C – Military and Civilian Personnel Serving in Afghanistan and Iraq

By Year, Month, Personnel Type, and Country of Deployment

As of: December 31, 2012

Source: CTS Deployment File

YEAR	MONTH	TOTAL			
		AFGHANISTAN ONLY	IRAQ ONLY	AFGHANISTAN AND IRAQ	TOTAL
2006	**01**	23,358	141,238	122	**164,718**
2006	**02**	26,209	133,243	63	**159,515**
2006	**03**	26,494	132,875	40	**159,409**
2006	**04**	26,850	131,991	49	**158,890**
2006	**05**	24,117	130,571	42	**154,730**
2006	**06**	24,214	127,458	56	**151,728**
2006	**07**	23,787	132,161	83	**156,031**
2006	**08**	23,624	143,752	63	**167,439**
2006	**09**	22,601	153,995	45	**176,641**
2006	**10**	21,218	156,667	52	**177,937**
2006	**11**	22,424	151,790	73	**174,287**
2006	**12**	22,237	133,146	46	**155,429**
2007	**01**	25,464	137,692	87	**163,243**
2007	**02**	26,254	141,269	78	**167,601**
2007	**03**	25,953	146,380	99	**172,432**
2007	**04**	25,918	152,780	115	**178,813**
2007	**05**	28,717	151,854	171	**180,742**
2007	**06**	25,619	158,137	114	**183,870**

2007	**07**	23,737	163,299	190	**187,226**
2007	**08**	23,889	171,712	110	**195,711**
2007	**09**	24,652	182,901	93	**207,646**
2007	**10**	24,989	184,099	176	**209,264**
2007	**11**	24,806	174,682	116	**199,604**
2007	**12**	26,479	163,033	110	**189,622**
2008	**01**	30,524	164,365	93	**194,982**
2008	**02**	29,214	161,058	113	**190,385**
2008	**03**	34,776	167,128	214	**202,118**
2008	**04**	36,917	168,550	267	**205,734**
2008	**05**	36,196	163,651	167	**200,014**
2008	**06**	34,280	157,105	185	**191,570**
2008	**07**	36,892	158,539	212	**195,643**
2008	**08**	34,989	152,949	256	**188,194**
2008	**09**	35,340	162,114	218	**197,672**
2008	**10**	33,961	167,555	273	**201,789**
2008	**11**	34,130	160,335	252	**194,717**
2008	**12**	37,017	155,438	224	**192,679**
2009	**01**	37,578	154,348	206	**192,132**
2009	**02**	37,932	150,677	238	**188,847**
2009	**03**	41,549	146,260	747	**188,556**
2009	**04**	43,254	138,010	856	**182,120**
2009	**05**	49,083	146,305	365	**195,753**
2009	**06**	54,440	130,891	724	**186,055**
2009	**07**	62,799	125,868	332	**188,999**
2009	**08**	67,168	135,655	630	**203,453**
2009	**09**	70,039	137,250	351	**207,640**

2009	**10**	76,182	128,430	534	**205,146**
2009	**11**	81,686	123,261	452	**205,399**
2009	**12**	84,272	119,608	384	**204,264**
2010	**01**	86,857	116,556	560	**203,973**
2010	**02**	90,094	105,680	360	**196,134**
2010	**03**	102,597	107,881	364	**210,842**
2010	**04**	102,358	109,145	452	**211,955**
2010	**05**	106,572	101,100	936	**208,608**
2010	**06**	108,249	94,767	486	**203,502**
2010	**07**	115,262	92,264	476	**208,002**
2010	**08**	115,109	74,536	377	**190,022**
2010	**09**	116,808	65,297	352	**182,457**
2010	**10**	119,751	61,391	368	**181,510**
2010	**11**	120,631	61,668	392	**182,691**
2010	**12**	115,294	62,072	392	**177,758**
2011	**01**	120,589	56,657	335	**177,581**
2011	**02**	123,177	60,057	653	**183,887**
2011	**03**	127,880	60,144	458	**188,482**
2011	**04**	127,908	55,227	390	**183,525**
2011	**05**	125,194	62,666	384	**188,244**
2011	**06**	124,210	62,205	311	**186,726**
2011	**07**	122,580	55,309	227	**178,116**
2011	**08**	119,835	59,405	285	**179,525**
2011	**09**	121,453	51,647	213	**173,313**
2011	**10**	122,133	46,962	185	**169,280**
2011	**11**	118,000	37,150	130	**155,280**
2011	**12**	121,359	16,448	152	**137,959**

2012	**01**	123,927	3,346	227	**127,500**
2012	**02**	121,529	2,945	91	**124,565**
2012	**03**	122,463	2,695	161	**125,319**
2012	**04**	119,926	2,376	285	**122,587**
2012	**05**	115,883	2,241	222	**118,346**
2012	**06**	111,354	2,157	247	**113,758**
2012	**07**	108,590	2,120	256	**110,966**
2012	**08**	105,037	2,117	219	**107,373**
2012	**09**	104,910	2,103	210	**107,223**
2012	**10**	94,543	2,077	46	**96,666**
2012	**11**	92,898	2,036	35	**94,969**
2012	**12**	91,551	2,014	76	**93,641**

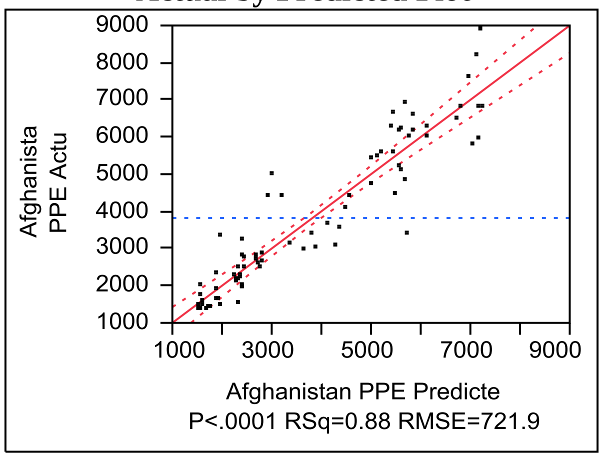
* "For Location Events beginning 19 March, 2003 and prior, if the reported country was unknown, the Deployment Country is categorized as Afghanistan".

Produced by Defense Manpower Data Center on February 11, 2013
DRS #61070

Appendix D – Full Data Results for GDSS2

Afghanistan Full Results

Response Afghanistan PPE
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.875859
RSquare Adj	0.869149
Root Mean Square Error	721.9762
Mean of Response	3821.101
Observations (or Sum Wgts)	79

Analysis of Variance

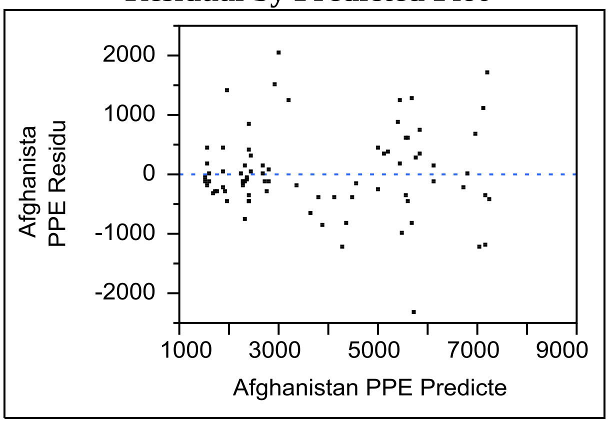
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	4	272142224	68035556	130.5239
Error	74	38572475	521249.66	**Prob > F**
C. Total	78	310714699		<.0001*

Parameter Estimates

Term	**Estimate**	**Std Error**	**t Ratio**	**Prob >|t|**
Intercept	716.24213	194.9017	3.67	0.0004*
12 Month Rotation	814.240	226.77	3.5	0.00

Term	Estimat	Std	t	Prob
	e	Error	Ratio	>|t|
	32	58	9	06*
Afghanistan BOG	0.03375	0.0024	13.	<.00
	07	69	67	01*
9 Month rotation	1295.66	587.17	2.2	0.03
	47	98	1	04*
Gloc closed	1047.53	564.46	1.8	0.06
	88	78	6	75

Residual by Predicted Plot



Prediction Expression

716.242131456961

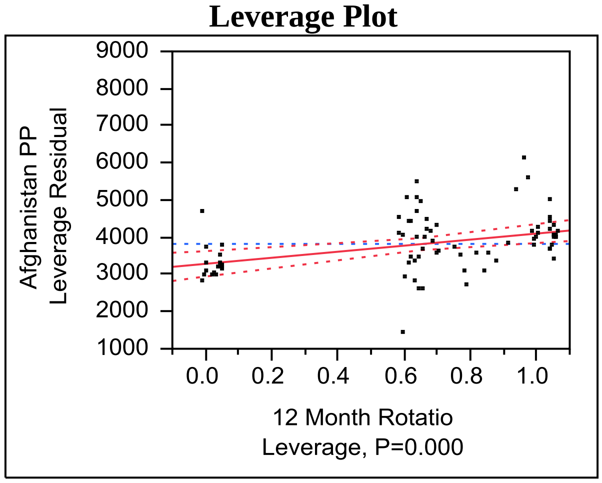
+ 814.24032344595 * 12 Month Rotation

+ 0.03375065221804 * Afghanistan BOG

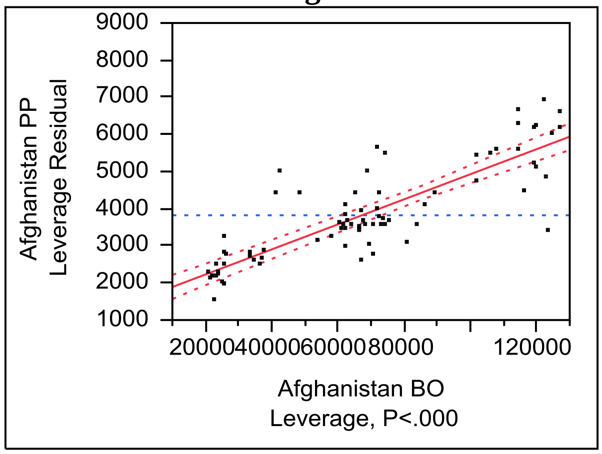
+ 1295.66468295074 * 9 Month rotation

+ 1047.53878803673 * Gloc closed

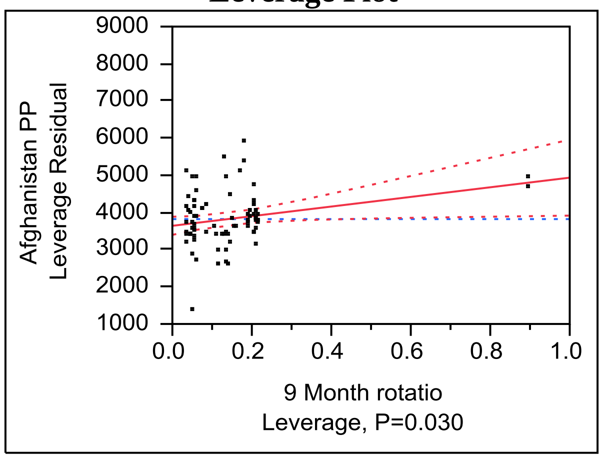
12 Month Rotation Leverage Plot



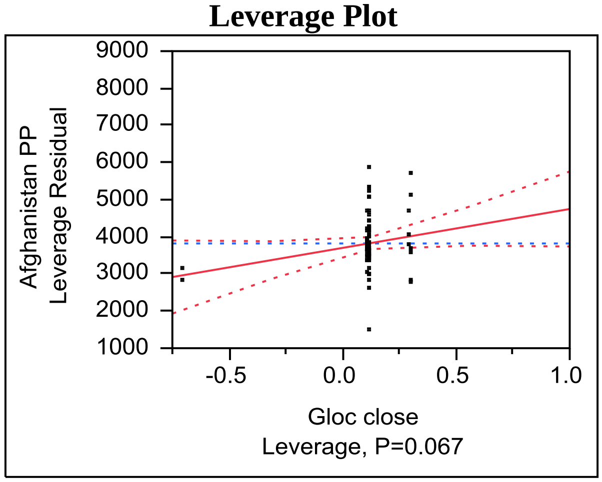
Afghanistan BOG
Leverage Plot



9 Month rotation
Leverage Plot



Gloc closed
Leverage Plot



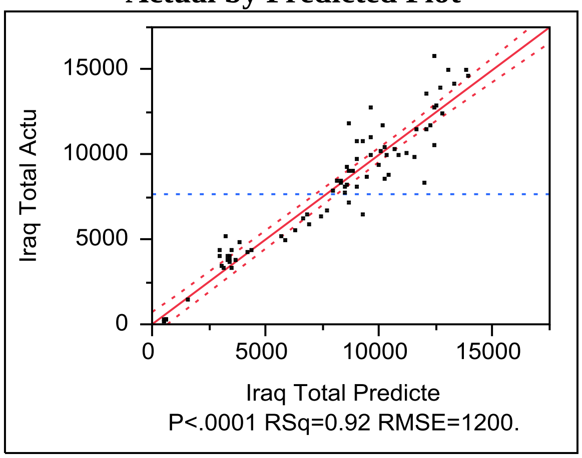
Durbin-Watson

Durbin-Watson	Number of Obs.	AutoCorrelation
1.3594335	79	0.3119

Iraq Full Results

Response Iraq Total
Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.915488
RSquare Adj	0.913264
Root Mean Square Error	1200.893
Mean of Response	7666.152
Observations (or Sum Wgts)	79

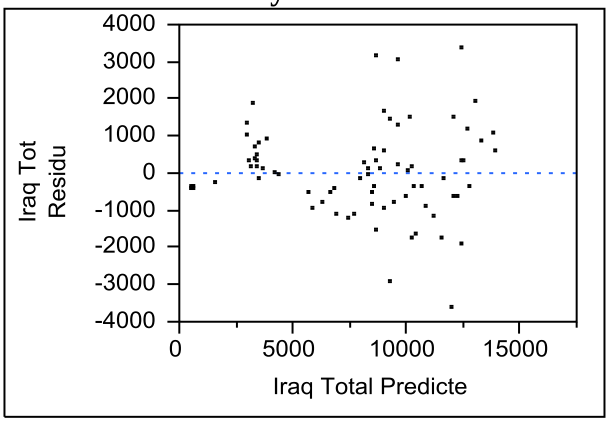
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	1187285008	593642504	411.6389
Error	76	109602931	1442143.8	**Prob > F**
C. Total	78	1296887938		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob >|t|
Intercept	396.67556	354.0317	1.12	0.2660
Iraq BOG	0.0736476	0.002574	28.61	<.0001*
12 Month Rotation	-1513.177	286.5915	-5.28	<.0001*

Residual by Predicted Plot



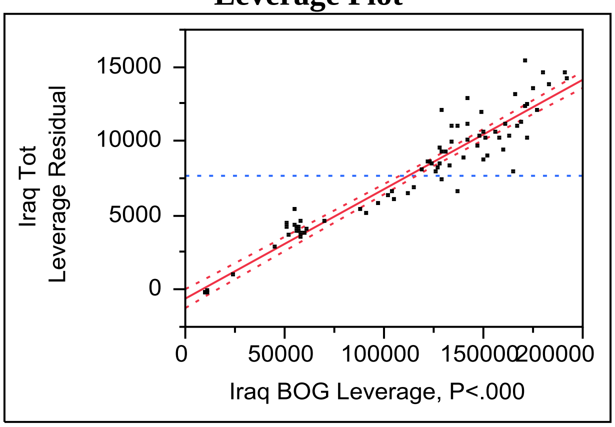
Prediction Expression

396.675559824516

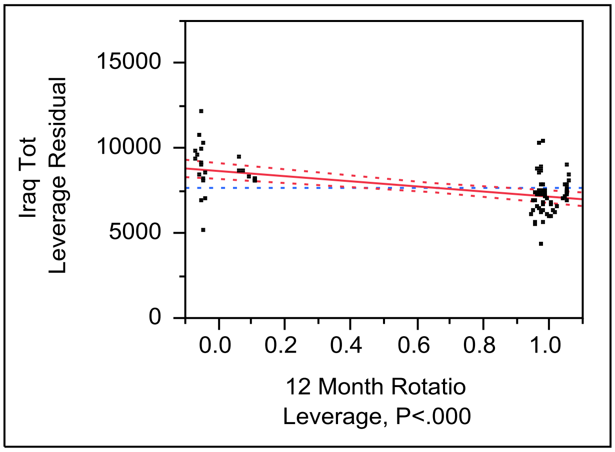
+ 0.07364763113676 * Iraq BOG

+ -1513.1766593637 * 12 Month Rotation

Iraq BOG Leverage Plot



12 Month Rotation
Leverage Plot



Durbin-Watson

Durbin-Watson	Number of Obs.	AutoCorrelation
.0326453	79	0.4438

Appendix E – Complete Data Set for GDSS2 Regression

Flight Date	Afghanistan PPE	Iraq PPE	Other PPE	TE Data	Afghanistan BOG	Iraq BOG	Total BOG	AFG % of Total	IRAQ % of Total	Afghanistan Total	Iraq Total	Total PPE
200601	1,551	5,385	1,139	-	23,358	141,238	164,596	0.14	0.86	1,716	6,359	8,075
200602	1,935	5,970	1,432	-	26,209	133,243	159,452	0.17	0.83	2,174	7,163	9,337
200603	2,469	7,683	1,552	-	26,494	132,875	159,369	0.17	0.83	2,733	8,971	11,704
200604	2,740	7,810	1,756	-	26,850	131,991	158,841	0.17	0.83	3,044	9,262	12,306
200605	2,237	6,415	1,480	-	24,117	130,571	154,688	0.16	0.84	2,478	7,654	10,132
200606	2,266	7,053	1,597	-	24,214	127,458	151,672	0.17	0.83	2,532	8,384	10,916
200607	2,473	7,277	1,126	-	23,787	132,161	155,948	0.16	0.84	2,652	8,224	10,876
200608	2,180	7,595	1,277	-	23,624	143,752	167,376	0.15	0.85	2,367	8,685	11,052
200609	2,168	7,304	1,348	-	22,601	153,995	176,596	0.13	0.87	2,347	8,473	10,820
200610	2,254	6,522	1,131	1,408	21,218	156,667	177,885	0.12	0.88	2,567	8,749	11,315
200611	2,146	6,390	1,096	3,176	22,424	151,790	174,214	0.13	0.87	2,712	10,096	12,808
200612	2,096	8,190	1,147	3,126	22,237	133,146	155,383	0.15	0.85	2,722	11,838	14,559
200701	2,021	6,545	956	3,986	25,464	137,692	163,156	0.16	0.84	2,813	10,695	13,508
200702	1,962	6,663	1,195	3,631	26,254	141,269	167,523	0.16	0.84	2,735	10,716	13,451
200703	2,794	7,386	1,276	4,985	25,953	146,380	172,333	0.15	0.85	3,756	12,685	16,441
200704	3,246	6,803	1,088	4,605	25,918	152,780	178,698	0.15	0.85	4,089	11,652	15,742
200705	1,364	4,236	642	6,033	28,717	151,854	180,571	0.16	0.84	2,446	9,829	12,275
200706	1,570	7,507	1,214	5,813	25,619	158,137	183,756	0.14	0.86	2,571	13,533	16,104
200707	1,376	6,218	1,116	6,380	23,737	163,299	187,036	0.13	0.87	2,356	12,734	15,090
200708	1,459	6,965	1,070	8,081	23,889	171,712	195,601	0.13	0.87	2,606	14,969	17,575
200709	1,359	7,227	916	7,856	24,652	182,901	207,553	0.12	0.88	2,428	14,931	17,358
200710	1,732	6,387	902	8,388	24,989	184,099	209,088	0.12	0.88	2,870	14,539	17,409
200711	1,994	6,402	702	8,149	24,806	174,682	199,488	0.13	0.87	3,122	14,125	17,247
200712	1,477	6,552	707	10,060	26,479	163,033	189,512	0.14	0.86	3,015	15,781	18,796
200801	1,437	5,100	791	8,370	30,524	164,365	194,889	0.16	0.84	2,900	12,798	15,698
200802	1,411	4,850	769	7,269	29,214	161,058	190,272	0.16	0.84	2,662	11,637	14,299
200803	1,658	7,138	854	7,333	34,776	167,128	201,904	0.17	0.83	3,083	13,900	16,983
200804	1,482	5,845	735	7,288	36,917	168,550	205,467	0.18	0.82	2,936	12,414	15,350
200805	1,637	5,325	688	5,702	36,196	163,651	199,847	0.18	0.82	2,803	10,549	13,352
200806	1,894	4,030	723	4,509	34,280	157,105	191,385	0.18	0.82	2,836	8,320	11,156
200807	3,359	5,817	1,005	5,893	36,892	158,539	195,431	0.19	0.81	4,666	11,408	16,074
200808	2,339	5,146	949	6,853	34,989	152,949	187,938	0.19	0.81	3,798	11,489	15,287
200809	2,585	4,324	1,185	5,642	35,340	162,114	197,454	0.18	0.82	3,813	9,923	13,736
200810	2,689	4,495	1,155	5,565	33,961	167,555	201,516	0.17	0.83	3,832	10,072	13,904
200811	2,816	4,306	886	6,407	34,130	160,335	194,465	0.18	0.82	4,107	10,307	14,415
200812	2,482	4,295	817	6,230	37,017	155,438	192,455	0.19	0.81	3,856	9,968	13,824
200901	2,658	4,310	711	6,879	37,578	154,348	191,926	0.20	0.80	4,167	10,391	14,558
200902	2,862	3,390	829	6,666	37,932	150,677	188,609	0.20	0.80	4,388	9,359	13,747
200903	4,429	3,800	701	8,479	41,549	146,260	187,809	0.22	0.78	6,468	10,941	17,409
200904	5,022	3,854	699	6,913	43,254	138,010	181,264	0.24	0.76	6,844	9,644	16,488
200905	4,413	3,293	930	7,890	49,083	146,305	195,388	0.25	0.75	6,641	9,885	16,526
200906	3,156	2,175	717	7,578	54,440	130,891	185,331	0.30	0.70	5,613	8,013	13,626
200907	2,988	2,675	917	7,682	62,799	125,868	188,667	0.33	0.67	5,866	8,396	14,262
200908	3,397	3,132	1,452	7,290	67,168	135,655	202,823	0.33	0.67	6,296	8,974	15,271
200909	3,028	2,890	1,644	6,144	70,039	137,250	207,289	0.34	0.66	5,659	8,047	13,706
200910	3,690	3,602	693	6,739	76,182	128,430	204,612	0.37	0.63	6,450	8,274	14,724
200911	3,070	3,206	919	6,669	81,686	123,261	204,947	0.40	0.60	6,087	7,777	13,864
200912	3,538	3,350	1,059	4,466	84,272	119,608	203,880	0.41	0.59	5,815	6,598	12,413
201001	4,078	2,942	1,427	4,329	86,857	116,556	203,413	0.43	0.57	6,527	6,249	12,776
201002	4,402	2,739	1,677	4,621	90,094	105,680	195,774	0.46	0.54	7,291	6,147	13,439
201003	4,715	3,378	2,024	3,854	102,597	107,881	210,478	0.49	0.51	7,574	6,396	13,971
201004	5,432	2,966	2,098	3,339	102,358	109,145	211,503	0.48	0.52	8,053	5,782	13,835
201005	5,460	2,300	1,710	4,837	106,572	101,100	207,672	0.51	0.49	8,800	5,508	14,307
201006	5,567	1,480	1,248	6,043	108,249	94,767	203,016	0.53	0.47	9,439	4,899	14,338
201007	6,645	1,930	1,487	5,711	115,262	92,264	207,526	0.55	0.45	10,628	5,145	15,773
201008	6,271	1,786	1,322	5,120	115,109	74,536	189,645	0.60	0.40	10,168	4,331	14,499
201009	4,461	1,226	1,127	5,967	116,808	65,297	182,105	0.64	0.36	8,996	3,785	12,781
201010	5,213	1,334	928	6,082	119,751	61,391	181,142	0.66	0.34	9,829	3,728	13,557
201011	5,126	1,837	823	5,296	120,631	61,668	182,299	0.66	0.34	9,161	3,922	13,082
201012	5,589	1,739	912	4,421	115,294	62,072	177,366	0.65	0.35	9,042	3,619	12,661
201101	6,212	1,514	852	4,918	120,589	56,657	177,246	0.68	0.32	10,123	3,373	13,496
201102	4,842	1,507	800	5,799	123,177	60,057	183,234	0.67	0.33	9,257	3,692	12,948
201103	6,582	1,822	894	5,924	127,880	60,144	188,024	0.68	0.32	11,202	4,020	15,222
201104	6,179	1,704	682	6,723	127,908	55,227	183,135	0.70	0.30	11,336	3,952	15,288
201105	6,034	1,596	989	7,022	125,194	62,666	187,860	0.66	0.34	11,346	4,295	15,641
201106	3,385	926	520	6,589	124,210	62,205	186,415	0.66	0.34	8,097	3,323	11,420
201107	6,921	1,708	1,368	6,792	122,580	55,309	177,889	0.69	0.31	12,520	4,269	16,789
201108	6,186	1,851	1,601	8,171	119,835	59,405	179,240	0.67	0.33	12,685	5,124	17,809
201109	6,254	1,758	1,349	6,815	121,453	51,647	173,100	0.70	0.30	11,955	4,222	16,176
201110	5,991	2,225	1,469	7,555	122,133	46,962	169,095	0.72	0.28	12,481	4,760	17,240
201111	5,800	1,350	1,183	6,790	118,000	37,150	155,150	0.76	0.24	11,857	3,267	15,123
201112	5,972	378	1,427	6,771	121,359	16,448	137,807	0.88	0.12	13,180	1,368	14,548
201201	6,810	35	1,550	4,748	123,927	3,346	127,273	0.97	0.03	12,933	210	13,143
201202	6,791	42	1,670	3,943	121,529	2,945	124,474	0.97	0.03	12,261	185	12,446
201203	8,879	80	2,283	4,506	122,463	2,695	125,158	0.98	0.02	15,502	247	15,748
201204	8,223	54	2,328	3,967	119,926	2,376	122,302	0.98	0.02	14,376	195	14,572
201205	7,625	35	2,286	4,647	115,883	2,241	118,124	0.98	0.02	14,402	191	14,593
201206	6,826	39	1,727	3,436	111,354	2,157	113,511	0.98	0.02	11,873	155	12,028
201207	6,487	29	1,876	2,875	108,590	2,120	110,710	0.98	0.02	11,131	136	11,267

Appendix F – Data Set and Results for OMRS

The full results and data set for the OMRS Database are Classified Secret. They can be obtained by authorized personnel through the Graduate School of Engineering and Management at the Air Force Institute of Technology.

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14. ABSTRACT
In today’s constrained budget environment, Air Mobility Command struggles with striking the right balance in the mobility force structure. There is political pressure to maintain the status quo, but financial constraints promote downsizing the number of tactical airlift aircraft in the inventory. There must be a dependable way to determine the amount of intra-theater airlift that is required for the force while ensuring assets are in place to provide it. This research explores an under researched area of study in the Mobility Air Force; namely, what are the actual requirements for intra-theater airlift in a sustained conflict. To achieve this, the researcher applied a backward linear regression analysis to a dataset obtained from an Air Mobility Command database and one from the USCENTCOM Theater of operations. Six years of data were compared to the number of people deployed to the Middle East region and other variables. The researcher attempted to determine what the most influential factors are in the demand for airlift and how those requirements change based on the number of personnel deployed to an Area of Operations. Prediction equations with high correlation coefficients were developed from the datasets and individual variables were examined to determine their effect.

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